PART I: BACKGROUND

Title:
A Case Study-Based Approach to Scientific Literacy: Application of Science Concepts and Lab Techniques to Understanding Antibiotic Resistance

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Discipline or Field:
Microbiology, Biology

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Course Name:
Introduction to Biology

Course Description:

Introduction to Biology is a freshmen-level 3-credit course, designed to expose non-science majors with basic concepts and principles in biology, focusing on aspects essential to scientific literacy. Students enrolled in this course gain experience in the process of biological experimentation. BIOL 100 fulfills the General Education science requirement "Apply Scientific Principles to the Natural World " (Appendix 1).

The lesson study was taught in separate course sections -- 60 students in Fall 2008 and 30 students in Spring 2009 -- where the majority (> 90) of students were first- or second semester freshmen. Students met twice per week (50 min per session) in a technology-enhanced classroom that accommodates 80 students in individual desks: this arrangement favored collaborative group (2-3 students) interactions described below. Lab meetings were held once per week (110 minutes per period) in a traditional lab setting with 30 students maximum per lab period; students self-selected collaborative group partners for the lesson study.

The lesson study, implemented early in each course, was the focus activity at least three times per lecture or lab each semester and was reviewed and/or interwoven throughout the curriculum during presentation of related topics. Large group meetings were held to

encourage sharing of general antibiotic resistance information, from which collaborative group assignments were derived and completed. For designated in-class lesson study sessions, small collaborative groups of 2-3 students completed required lab activities, reviewed literature and lab results, and discussed and prepared their final presentation of their antibiotic resistance project. Additionally, collaborative groups completed antibiotic resistance project activities outside-of-class to meet course requirements. The culmination of the lesson study was collaborative-group presentation of the course project via PowerPoint slides.

Since professionals currently view antibiotic resistance as a global health crisis, our approach was to introduce the concept- and lab-based approaches employed by medical and public health professionals investigating this issue. To address general education goals of "experience in the process of biological science through experimentation", the lesson study was designed as a problem-based course project where background information was initially presented in a case-study format (Appendix 2). Students were assigned to role-play as public health interns investigating an outbreak of antibiotic-resistant *Escherichia coli* (referred to in this document as *E. coli*) in a small community. The overall lesson study systematically reviewed background concepts and lab techniques related to antibiotic resistance and analysis for *E. coli*. Since *E. coli* outbreaks and antibiotic resistance are current events in the popular press, the lesson study provided students an opportunity to learn the "science" required to address these "real-world" public health issues.

Executive Summary:

The theme of the lesson study was the concept- and lab-based investigation of antibiotic resistance.

Learning goals.

Students will be able to:

1. *explain* the basic **scientific concepts** related to the study of antibiotic resistance.
2. *describe* the **methods** used to investigate bacterial antibiotic resistance.
3. *relate* their **overall knowledge of antibiotic resistance** based on application of concept- and data-based knowledge and experience.

Instructional design.

The problem-based lesson study employed a case study framework where students role-played as public health interns investigating a community outbreak of antibiotic-resistant bacterial species *E. coli*. As described in the *Learning goals*, the three major aspects of the lesson study, *conceptual* knowledge, collection and application of *data-based* knowledge, and communication of *overall* knowledge, culminated in an oral presentation of each

group's project. In addition to meeting campus general education requirements, the collaborative group format of the project addresses one of our departmental program goals (Appendix 3) and was assessed in a narrative fashion (Appendix 4) by individual students at the end of the project.

Our approach was straightforward in that both lecture and lab sessions introduced, discussed, and reviewed biological concepts related to antibiotic resistance and application of the scientific method process to "solve and explain" the issues set forth in the case study. The focus of the lab was to approximate standard microbiological methods used by public health professionals to test antibiotic resistance of *E. coli*. Lastly, students were evaluated on their overall knowledge via an oral PowerPoint presentation.

Major findings about student learning.

The majority of students were able to clearly communicate their understanding of antibiotic resistance using the case-study framework. Having the case-study allowed students to research similar published studies to formulate hypotheses, compare data, and discuss outcomes of their "internship". Application of standard methods used to collect data about antibiotic resistance of E. coli was completed in collaborative groups where students (in both lesson study sessions) were successful in explaining and applying their data to the case-study scenario. Students were able to utilize the strengths of group members to compile their project data and researched background information to present their projects in a PowerPoint format in language understandable to peers and instructors. Upon the second iteration of the lesson, instructors were able to implement the student suggestions (from the initial lesson) to improve student comprehension of concepts and facilitate collaborative groups via additional in-class time set aside specifically for the project. Student self-assessment of the project through a narrative format revealed positive changes in student comprehension with respect to previous misconceptions regarding, for example, differences between bacteria and viruses and human resistance to antibiotics. Students were clearly able to articulate basic information about antibiotics, *E. coli*, and the impact of these topics on their personal lives.

PART II: THE LESSON

How to Teach the Lesson

Lesson study steps. The initial introduction to the project is given during the first day of class when reviewing the course syllabus. As the course progresses, students learn more about the concepts in lecture and lab, and applicable material is reviewed throughout various lecture topics. The project lab techniques are accomplished over several weeks where students practice and review the techniques prior to the actual start of the project. Each instructor incorporated the lesson study material based on the overall lab schedule for all the department's introductory labs due to space and equipment limitations. The

following lesson plan is the basic order of how the study was accomplished, although the actual time spent on each step varied due to scheduling and thus is omitted.

Pre-lesson work.

Preparation

• Copies of the case study (Appendix 3), lab methods packet (Appendix 5), and IRB form (Appendix 6) are made. See links. Other: index cards for collaborative group contact information exchange (one per student); formal lesson study/project handouts (see examples for this lesson study in Appendices 7-13); example exam questions (Appendix 14); and lab materials preparation schedule (see Appendix 15).

• During the first few weeks of the course, students are informed of introductory curriculum (e.g., prokaryotes and microscopes) that is applicable for the course project. Because the lesson study and the course project are "one and the same", and the course project is required of all students, there is no mention of the lesson study at the very beginning of the course.

Introduction

• Two to three weeks into the course, when students and instructor are familiar with one another and the overall course format, the lesson study is introduced formally. Students are informed of the lesson study and its goals, and the IRB form (Appendix 6) is distributed and explained. Students are reassured their grade for the project is not dependent on their participation, and that any aspect of the lesson study participation is assessed separately and anonymously. Students are directed to re-read the IRB form on their own, contact the listed personnel with any further questions, etc., prior to signing the permission section. A due date is given for the form and students are encouraged to submit the form regardless of their choice by that date. Other instructors involved in lesson study are also introduced at this time.

• Following collection of the IRB form, the formal lesson plan and associated observations can begin. At instructor discretion, the lecture or lab period can be used to describe the course project requirements. Other instructors are informed of lesson study participants and a schedule is confirmed for study observations, discussions, and/or task assignments.

• For our lesson study, by Week 4 of the course, the lesson study was begun in both lecture and lab as the course project is spread out of several weeks due to the lab aspects of the project. All students are given the case study during their lab section since the smaller group (30 students) facilitates discussion between students and/or instructor. Other instructors make observations of these initial interactions during this case study review period.

The lesson plan.

Step 1 (~ 10 minutes)

• The case study is distributed and the instructor reads the case study as students follow along.

Step 2 (~ 20 minutes)

• Students are instructed to complete the following tasks during this time:

- Self-select collaborative groups (2-3 students per group), and exchange contact and schedule information to ensure that group meeting times can be arranged with minimal conflicts. If there appears to be any conflict, students are asked to find a group that will better meet their needs.

- Re-read and review the case study in the collaborative group and develop questions about the case study concepts that need to be explored or explained in more detail (see Appendix 9 for an example of a formal handout). Each group member is required to contribute a question, and the group should have a minimum of 4 questions. Questions are turned in at the end of session; instructor prepares master list for distribution at next meeting.

- NOTE: The case study question/answers will be reviewed often (future lecture and lab) and students will hopefully share their knowledge as they learn the lesson study material. Additionally, the questions can be used as quiz or exam material when appropriate.

Step 3 (~ 30 minutes)

• Instructor brings collaborative groups back to the larger class group and a brief oral sharing of questions by each member occurs per group. Even if similar to other group questions, students are required to share. Students are asked to compare "notes", and if possible, answer classmates questions based on previous knowledge or experience.

NOTE: This "discovery" session will most likely reassure students that most peers are "on the same page" with respect to *E. coli*, antibiotic resistance, and lab techniques. Since this is a non-majors course, we expected that the students would have little, if any background and many misconceptions with the case study topics. This session allows instructors to "flush out" key concepts to discuss and review during future lecture and lab sessions.

Step 4 (~ 20 minutes)

• Instructor describes individual homework assignment; however, the assignment can be completed together to promote collaborative group interactions. Students are given one week to complete assignment.

- Assignment is to find and bring to class:
  - one current (maximum 1 year old) article about antibiotic resistance from a reliable source
  - make list of "know" and "need to find out" statements (see Appendix 9)
  - be prepared for share/discussion session
  - record source information for project references (see Appendix 11)

- Instructor gives examples of such sources:
  - website: Center for Disease Control (CDC)
  - peer-reviewed journal: American Society of Microbiology journals
  - popular press: local newspaper, TIME or Newsweek magazines

Step 5 (variable time – suggested times given)

Depending on how the *E. coli* is to be acquired by the students (purification from an environmental sample or standard lab strain provided by instructor) this aspect of the project varies in time and instruction as described below. Instructor can provide the environmental sample or can allow students to bring in a sample they are interested in analyzing. In this step of the lesson study, students complete main two tasks during the 110-minute lab period, specifically the (a) instructor-led hands-on lab techniques and (b) instructor-facilitated write-up of project sections. Students are encouraged to bring laptops. If time permits in any of these lab periods, the instructor can review/discuss the Step 2/3 case study question/answer activity, Step 4 activity, or other pertinent information.

• Environmental sample (up to 5 lab periods, Appendices 6, 12).
- Period 1.
  - Instructor provides samples, e.g., sewage treatment plant water, non-human feces (such as those collected from a farm) and leads large group through dilution series and initial plating (60 minutes).
  - Instructor works initially work with the large group, leading a discussion of the completed techniques as well as the upcoming techniques for subsequent labs. The remaining lab time is spent as a break-out session where the smaller collaborative groups begin a rough draft "Materials and Methods" write-up; the instructor is present for clarification of terms, writing style, etc. (50 minutes). This format of large group review, followed by collaborative group break-out session, occurs for all subsequent lab periods described below.

- Period 2.
  - Instructor leads large group through purification procedures and practice with master plate preparation and replica plating. Students complete lab techniques using their period 1 "Materials and Methods" write-up. Large group/break-out session (60 minutes).
  - The remaining lab period is spent in the large group/collaborative group format described above. First, the instructor reviews the Step 4 assignment to resolve misconceptions, define terms, answer questions, etc., followed by rough draft "Introduction" write-up and "Materials and Methods" corrections (50 minutes).
  - Instructor can follow through with the activities for period 2 as described but can opt for a third purification if needed to obtain *E. coli*. If this option is chosen, then *E. coli* would be available period 4 instead of period 3.

- Period 3.
  - Instructor leads large group through master plate preparation and students follow using their "Materials and Methods" write-up. Large group/break-out session (60 minutes).
  - The remaining lab time is used for activities at the discretion of the instructor.

- Period 4.
  - Instructor leads large group through replica plating for antibiotic testing and students follow using their "Materials and Methods" write-up. Large group/break-out session (60 minutes).
  - The remaining lab time is used for activities at the discretion of the instructor.

- Period 5.
  - Instructor leads large group through analysis of antibiotic testing results and students follow using their "Materials and Methods" write-up and record data. Large group/break-out session (60 minutes).
  - The remaining lab time is used for activities at the discretion of the instructor.

• *Lab strain provided* by instructor can follow the basic lab procedures in Appendix 6 with omissions as follows: (a) omit the dilution series step but complete the purification step, and (b) discussions and write-ups occur as above but the timeframe is decreased by one lab period.

Post-lesson work.

<u>Step 6</u> (~ 50 minutes in lecture)

• Instructor describes group presentation using examples of statements, tables, graphs, etc. to display and orally discuss project requirements while students follow the grading rubric and other handouts (Appendices 11, 13). Break-out session for the remainder of class for students to ask specific questions pertinent for their group. Students are encouraged to bring laptops and/or to have hard copies of completed work.

Step 7 (~ 50 minutes/lecture or ~110 minutes/lab period)

• Instructor assigns one project release day for students and is available for specific questions. This structure allows students with scheduling issues (which tends to be the majority of our students) to have a definite, focused scheduled meeting time to work on project.

Step 8 (~15 min per collaborative group)

• Lecture and/or lab period(s) are reserved for collaborative group final project PowerPoint presentations for assessment purposes. The presentation assessment (Appendices 11, 13) was used to determine if the students achieved the initial goals (see p 3 of this document) and had achieved a basic understanding of antibiotic resistance and the lab methods required to test for bacterial resistance to commonly used antibiotics. Additionally, overall lesson study assessment was accomplished by using the:

- *exam questions* (Appendix 14) to assess an individual's knowledge base,
- *self-assessment narrative tool* (Appendix 4) to reveal an individual's perception of concepts and the project, and a
- *combination of all three* (presentation, exam, narrative) to exact changes to both lesson study efforts to improve the course project.

Student Learning Goals

Upon completion of the lesson study, students should be able to:

1) *explain* the basic concepts of antibiotic resistance.
2) *describe* methods that can be used to determine bacterial resistance to antibiotics.
3) *relate* the acquired information to their own personal lives, lifestyles, and habits.

The immediate and long-term academic learning goals are intertwined. For a majority of these non-science majors, experiencing the pragmatic nature of the scientific method via the case study was most likely a novel approach to establish critical thinking skills that can be applied elsewhere in the students' academic lives. Likewise, the lesson's knowledge-based concepts engage and raise awareness of the socioeconomic and health issues associated with antibiotic resistance. In turn, students can assume the role of "teacher" and educate peers and family with respect to bacteria in general, popular press reports concerned with lesson issues, and the "pros and cons" of antimicrobial products available

to consumers. Additionally, the collaborative group format familiarizes students with their own, as well as others, strengths and weaknesses: many students commented on the respectful nature of their group interactions and personal contributions to the overall project effort. In this respect, the project hopefully provided a framework for an individual student's academic and personal goal-setting so that he/she can work toward attributes that are valued in the professional world.

How the Lesson is Intended to Work

The basic structure of the lesson is for the instructor to facilitate students' understanding of antibiotic resistance and the lab-based analyses that are employed to identify disease-causing (pathogenic) bacteria that are resistant to commonly prescribed antibiotics.

• Students are given reading and research assignments that cover basic concepts related to antibiotic resistance and *E. coli*, the project bacterial species (see Appendices 7-9 for examples of instructional materials). Students construct their own learning "tools" via collaborative group sharing of their pre-lesson knowledge, and continue this discovery-and-application approach throughout the project.

• The lesson design emphasizes the instructor's role to assist students in their connection the project components – case study, lab, concepts – into an understandable context.

PART III: THE STUDY

Approach

The major focus for the lesson was to develop students' understanding of how scientists solve problems using the timely topic of antibiotic resistance and the oft-reported bacterial species *E. coli*. Since we teach the upper division microbiology course, the starting point for this lesson study was apparent: our experience taught us that most science majors have only heard of *E. coli*, and perhaps antibiotic resistance, hence we posited then that most non-majors would have less knowledge of these topics.

During in-class lesson periods, the instructors observed student groups by attending lab activities and lectures, taking notes anonymously in the back of each room. Observers noted students' verbal interactions with each other, how they worked (e.g., organizing data using a laptop or by hand), and the amount of time spent on the project during the allotted class time. The student self-assessment narrative was the primary tool used to determine whether the lesson accomplished its goals. Additionally, article assignments and student-instructor interactions, the final project PowerPoint presentation, and to a lesser extent exams/quizzes, were also evaluated for student understanding of antibiotic resistance and the effectiveness of the case-study approach. In general we determined that an increase

allocation of in-class time for student interactions with each other and with the instructor would promote comprehension of the concepts and techniques used for the antibiotic resistance investigation.

Findings & Discussion

Basic concepts of bacteria and antibiotic resistance
Observations during the initial project sessions --1) "already know" and "need to know" information, 2) choices of relevant articles, and 3) large and small group discussions -- revealed that an emphasis on basic concepts would require more class time than initially planned (Appendix 9). We then relied mainly of the self-assessment narrative to restructure the lesson study to enhance instructor-student interactions to promote topic comprehension. We emphasized increased class time devoted to instructor-led large group discussions with small group follow-up to promote collaborative group interactions where students could explore concepts more comfortably with their project partners.

Collaborative groups and accomplishment of lesson study goals
Students found their collaborative group experience positive and helpful toward completion of the course project as summarized in Table 1. Review of the self-assessment narrative from each semester reflected that sharing the workload and communication (e.g., "getting along" and "respectful of one another") were important for a successful group. Still, while these group interactions were scheduled during class sessions, the majority of collaborative work occurred outside of class where students noted factors, such as schedule coordination, as a key element to accomplish the project.

This important observation was used to increase in-class time for collaborative interactions as described below. We also noted that students acted independently once establishment of the collaborative groups occurred and students were familiar with their self-assigned tasks ("sharing workload").

Interestingly, responses reported "areas for group improvement" were similar to that of success areas. We revamped areas of concern (see Table 1 - indicated by an asterisk *) for the second lesson study group because we interpreted these responses to mean that overall, more dedicated in-class time was required for collaboration. As such, students were encouraged to find group members with similar class, work, and commuting schedules to alleviate potential conflicts. We observed that during the second semester, some groups changed members early in the lesson after discovering that their schedules did not work smoothly. Likewise, PowerPoint presentations were downloaded onto a single departmental computer instead of allowing students to use their own laptops. This change "leveled the playing field" as there was one due date for all completed slide shows, regardless of the actual group presentation date.

Table 1. Summary of self-assessment evaluation of group performance.

Assessment category	Student response (%[1])
Successful group interaction & knowledge acquisition	Sharing workload (67) Communication (55) Research/preparedness/understanding of concepts (39) Organization (21) Schedule coordination (19) PowerPoint presentation (13) Time management (13)
Areas for group improvement	Organization (45) PowerPoint presentation (33) Schedule coordination (35)* Research/preparedness/understanding of concepts (26) Communication (17) Time management (11) Expectations of group members by each other (9)* Laptop issues (4)* Expectations of instructor (2)* Ask instructor more questions about project (2)*

[1] Given values were calculated by grouping of language (phrases, terms, etc.) used by students to respond to narrative sections. Assignment of related responses were then complied as a percentage of total students for both semesters that completed the narrative as shown in "Student response".

To facilitate and enhance student interactions within collaborative groups or with the instructor, additional class time, even if only 10 minutes, was set-aside during most non-project labs for questions, review of project assignments (e.g., data analyses, PowerPoint presentations) since all group members were present at the same time. While not a formal observation period, these brief sessions allowed the instructor to take mental notes and address student-raised issues at the next class meeting, or convey the information via email and/or Desire2Learn (D2L) ^{TM} posting.

Observations during the second semester gave the impression that students focused more on the tasks at hand as the majority of groups took advantage of allotted lecture and lab time to organize project information and inquire about methods, data interpretation, or presentation format. Review of the second semester narratives appear to somewhat support the implemented lesson study changes in that "Organization" (14%) and "Time management" (0%) concerns decreased compared to the first semester; however "Communication" and "Schedule coordination" comments still was comparable for both semesters. Additionally, second semester students were given guidelines for their presentations (Appendix 11) – where information to be contained on each slide was listed and further reviewed with examples. Yet, even with the changes, second semester students

responded similarly to first-semester students with respect to inadequate preparation or practice of their PowerPoint presentations.

Assessment of lesson study goals
We used a combination of the narrative, presentation, and exam formats to measure achievement of lesson study goals (see Table 2 and described elsewhere in this report).

Table 2. Summary (both semesters) of student learning regarding project topics.

Assessed lesson study goal	Assessment tool	Assessment summary (%[1])
explain the basic concepts of antibiotic resistance	presentation	80
	exam[2]	98
	narrative	95
describe methods that can be used to determine bacterial resistance to antibiotics	presentation	90
	exam	N/A[3]
	narrative	100
relate the acquired information to their own personal lives, lifestyles, and habits	presentation	N/A
	exam	100
	narrative	100

[1]The reported percentage refers to students from both semesters that provided acceptable responses (≥ 70%) to specific presentation criteria (Appendix 11, 13) or the written exam (Appendix 14). For the self-assessment narrative, the reported percentage is based on responses that addressed the lesson goal favorably or correctly.
[2]Exam results are reported from second semester only.
[3]There was no direct evidence from the tool for a particular goal.

We concluded that most students have an improved understanding of bacteria and antibiotic resistance. Surprisingly, some goal requirements were not met even at a basic level: for example, the 90% assessment summary value for "*describe* methods…" reflects one group that did not speak about methods because they used up all of their presentation time addressing introductory material, and another group that completely omitted any slides describing their project methods. For groups that fell into this category, it was difficult to assess the goals unless addressed by the students themselves via other tools since the anonymity of the study prevented most data collection small group of students. However, if time permitted, we could address these omissions in the question/answer session allotted with each presentation and duly noted student responses.

In general, students seemed to grasp the basic concepts of antibiotic resistance and stated that they had more awareness of the overall topics and/or would share their knowledge with family members (Appendix 4). For example, many students were able to apply lesson study concepts as summarized in narratives -- "bacteria can be good and bad"; " I'll complete my antibiotic dose"; and "people and organizations should act more responsibly to avoid continued promotion of antibiotic resistance". We also noted that the case-study approach allowed students to learn and comprehend lab methods in a given context, which was further exhibited by incorporation of students' initial articles into their presentation

introduction and discussion sections. Other interesting insights to student perceptions were gained from the narratives with respect to lab methods:

"I need to work on math graphs and using data. I have a hard time with logic thinking which is something that is common"

"I need improvement at recording my information, I should write more in detail of what I have done"

Overall, lesson study changes were made based on formal and informal classroom observations by the instructors and the student self-assessment narrative. We intervened by way of increasing interactions through the rescheduling of class time, streamlining the lab procedures, and providing guidelines for the PowerPoint presentation. We felt we had adjusted the curriculum as much as feasibly possible to accommodate the concerns listed in the narrative, and that schedule conflicts are inherently present within groups. The assessment tools also provided evidence that comprehension of antibiotic resistance concepts was largely accomplished using our case study and lab-based approach.

APPENDIX

Appendix 1:
- BIOL_100 Course Description (http://uwrf.edu/biology/assessment.htm)
- UWRF General Education Goal Three: Apply Scientific Principles to Natural World (http://www.uwrf.edu/registrar/GeneralEducation.htm)

Appendix 2: Case study, "Agricultural community experiences outbreak of *E. coli* intestinal infection"
Appendix 3:
- UWRF Biology Department Program Assessment Plan (http://uwrf.edu/biology/assessment.htm)

Appendix 4: Project Narrative Assessment & example student responses
Appendix 5: IRB form
Appendix 6: Lab Methods Packet
Appendix 7: Prokaryotic cells (example lecture handout)
Appendix 8: Basic information about *E. coli* (instructor-provided internet sites)
Appendix 9: Example research article (from instructor) and example student-provided articles & activity responses
Appendix 10: Epidemiology activity
Appendix 11: Project rubric and presentation guidelines
Appendix 12: Project schedule
Appendix 13: Project write-up and grading packet
Appendix 14: Exam questions & answers (examples)
Appendix 15: Lab materials preparation schedule