Clarity in Teaching and Active Learning in Undergraduate Microbiology Course for Non-Majors

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Abstract: We investigated a pedagogical innovation in an undergraduate microbiology course (Microbes and Society) for non-majors and education majors. The goals of the curriculum and pedagogical transformation were to promote active learning and concentrate on clarity in teaching. This course was part of a longitudinal project (Project Nexus) which prepares, supports and sustains upper elementary and middle level specialist science teachers. We sought to understand the impact of the course in terms of students' content understanding and in terms of students' feedback to the course. To determine students' content understanding we used a pre-post content survey. To document the use of teaching innovative approaches in the class we interviewed all participants, including the lecture and the lab instructors and their students, to get their perspectives. Also, all lecture classes and laboratory sessions were videotaped and observed by three university science educators. Our findings suggested that the instructor taught in the way that he planned. Positively, while the course placed an emphasis on modeling good pedagogy and promoting teaching science as a career option, significant gain in science content was achieved by the students.

Key words: Non-major science course, active learning, clarity in teaching, microbiology.

INTRODUCTION

The primary objectives of non-majors science courses are to introduce students to the process of scientific thinking, to help students gain an appreciation for how science is conducted, understand how science impacts daily lives and to provide a knowledge base in a particular scientific field that students can use as a foundation for life-long learning in the sciences. In this study we investigated pedagogical innovation in an undergraduate microbiology course (Microbes and Society) for non-majors and education majors. For over five years the course, which weekly consisted of two lecture sessions and two laboratory sessions, had been under transformation by the same biology professor. The goals of the curriculum and pedagogical transformation were to promote active learning and concentrate on clarity in teaching. Studies have shown that student learning is enhanced when they are actively involved in the teaching-learning process (Allen, & Tanner, 2006, Ebert-May et. al. 1997, Johnson et. al. 1998, Udovic et. al. 2002). There are many different types of active learning, all of which involve the students being engaged with the material, rather than passively listening to lectures. Many active learning techniques involve some form of cooperative learning in which students work together in groups toward some goal (Slish, 2005). The Microbes and Society course active learning aspects included: encouragement of student questions, the use of multimedia (i.e., videotape films) and instructional technology, small group activities, whole class discussions, student projects and the use of alternative assessments. All are best practice approaches for high-quality science teaching recommended by latest national standard reports (AAAS, 1993; NRC, 1996, 2007) and could be implemented in any science course for non-majors.

Clarity in teaching means teaching in a way that enables students to better understand the content, the processes, and their own learning. Research shows clarity to be a valid, distinct, and stable construct, unaffected by extraneous student or teacher variables (Hativa, 2000). Hativa (2000) reported that several dozen teacher behaviors were identified as components of clear teaching at the college level. Some of the main behaviors were: using examples and illustrations, presenting a material in a simple and logical manner, using questioning in class to gauge student understanding, repeating, stressing and summarizing important points, breaking down the material into small steps, and adapting the teaching to students' background knowledge and everyday life experience.

The Microbes and Society course is part of a longitudinal project (Project Nexus). Project Nexus [PN] is funded project by the National Science Foundation's Teacher Professional Continuum program (TPC). Project Nexus is designed to develop and test a science teacher professional development model that prepares, supports and sustains upper elementary and middle level specialist science teachers. Since the Microbes and Society course is a facet of Project Nexus, an innovation by the instructor is to highlight the connection between science and teaching. Interested readers are invited to learn more about Project Nexus by visiting www.projectnexus.umd.

In this study we focused on the innovative teaching approaches (active learning, clarity in teaching and connection between science and teaching) that were used in the transformative lecture section. We assessed the success of achieving our goals using observers' evaluations, the instructor's perspectives and students' achievements and feedback.

METHODS

Course Description

The course Microbes and Society was a 4-credit course, with 75 minutes twice a week lecture sessions and twice a week one-hour laboratory sessions. Microbes and Society looked at the fascinating roles that microbes play in the world around us. The course helped students develop an understanding of basic concepts in biology: the unity of life, evolution, disease, antibiotic resistance, the roles microbes play in providing food and recycling waste, and the roles that cultural and societal influences play in the spread control of microbial diseases.

The course was designed to enable students to develop lifelong learning skills, an appreciation and understanding of science, and the ability to explain science to others. The course used a variety of teaching strategies applicable to both science and non-science courses from the elementary through college level. It was based on a 12-part video series Unseen Life on Earth (*http://www.learner.org/resources/series121.html*). The videos were used in the class in an interactive manner by incorporating small group and whole class discussions after each section of the video. The instructor asked questions and encouraged student questions. An important goal of the course was to model teaching for all (for different students with different background and different learning styles) with the hope that students who pursue teaching as a career would learn how to teach all learners.

Learners in the Course

Twenty seven students were enrolled in the course. They were recruited by proactive techniques such as the posting of an engaging flyer for the course on bulletin boards throughout the campus, particularly in the College of Education and in the various non-science buildings. In addition, undergraduate advisors across campus were notified of the course and were encouraged to recommend it to students who needed a science course or wanted to experience learning science for diverse population in an active learning environment.

The recruited students represented diversity across several dimensions. Figure 1 shows students' demographic distribution (data obtained from 24 students who responded to a survey that included questions regarding their self-reported demographic identification).

Gender:	15 females 9 males
Number of Credit (earned up to entering the course):	13 between 0 to 30 8 between 31 to 60 3 between 61 to 90.
Ethnicity:	1 African-American 3 Asian 2 Hispanic 13 Caucasian 5 others.
Year at school:	15 Freshmen 7 Sophomores 1 Junior 1 Senior.
Major:	12 in education programs with other major 12 are not in education program and are coming from different major such as Journalism, Computer Sciences, Sociology, Music Theatre, Mathematics, and Government & Politics.

Fig. 1. Student background information (self reported – 24 students).

Instrumentation

In this study we sought to understand the impact of the course in terms of students' content understanding and in terms of students' feedback to the course. To determine students' content understanding we used a pre-post content survey (the survey may be obtained by request from the authors). The course's instructor formulated the content questions based on information from the National Science Education Standards. The survey included 20 multiple-choice questions: Four chemistry questions (i.e. The smallest units of matter are: a. atoms; b. molecules; c. atomic particles; d. microbes; e. cells), 8 molecular biology questions (i.e., Genetic information is stored in: a. proteins; b. lipids; c. enzymes; d. DNA; e. RNA), and 8 biology questions (i.e., The smallest units of living matter are: a. organisms; b. cells, c. nuclei; d. organelles; e. viruses). The topics discussed in the course were primarily from the biology and molecular biology domains. Therefore the four chemistry questions served as a baseline to compare students' improvement on the topics that were taught in the class. Students' feedback for the course was obtained via an extensive end-of-semester survey. The questions had an opening sentence and five different hierarchical categories. Students were asked to choose one answer (see examples in the results section).

To document the use of innovative teaching approaches in the class, one member of the research team (McGinnis) interviewed a representative sample of the class (N=6) on two occasions, once near the beginning of the semester, and once near the end of the semester. We used a structured interview protocol that consisted of four questions. As a research team we also interviewed the lecture and the lab instructors to gain their perspectives.

During class sessions it is difficult for science instructors to determine what impact their teaching has on students or even whether their teaching approach in actual practice matches their personal perception of practice. Discouragingly, a relatively large body of research suggests even those teachers who describe themselves as holding a constructivist perspective on teaching and learning, are seen by their students and by experienced observers to be teaching more conventionally than they thought they were (Salish I, 1997).

Therefore, in our study all lecture classes and laboratory sessions were videotaped and observed by three university science educators (our research team). One observer was a female professor who serves as the director of the University College of Chemical and Life Science Teaching and Learning Center, one was a male science education professor in the Curriculum and Instruction department, and the third was a female science education graduate student with a biology background. As a team they attended every class session, and took extensive notes that focused on documenting and interpreting the nature of the classes and the degree to which the instructional objectives were achieved.

FINDINGS

Three observers regularly visited the class sessions to take notes and document how and to what extent the instructor included strategies that promoted "active learning," "teaching in clarity," and "connection between science and teaching." All sessions were videotaped. Table 1 shows representative examples from the pedagogical strategies that were documented in the classroom. Below we elaborate on each of the innovative strategies reporting the instructor's perspective that he gave in formal interviews.

Active Learning Approaches

Students' and instructor's questions

The instructor encouraged students' questions in-class and out-of-class, modeling for students that science is a constantly expanding field which is based on progressive research. The instructor also explained during the interview some of the strategies he used to encourage students' questions and improve the quality of students' questions. For example, instead of answering a question directly, he might ask the group to respond to the question to encourage peer participation. As he reflected on the experience, he described his aspirations and observations, "And so what we're looking for, is to move as many of the students as we can forward in terms of asking questions that go beyond will this be on the test or is this content directed, and trying to put it into a bigger context. With some students we were successful and with others we were not." Students were also asked on ten occasions over the course of the semester to write as a homework assignment one question that they want to ask the instructor.

Multiple channels of communication

The instructor used multiple channels of communication with the students: Power-point presentations, white board, and videotapes. In an interview early in the course regarding his plans and goals for the course, the instructor described the lecture portion of the course, which was based on a 12 part video series, as a sequence of guided viewings of the videos followed by discussions. He indicated that he planned to make the class time interactive, spending only a small amount of time lecturing to the students. His hope was that the interactions would lead the students to the key concepts presented in the videos. In an interview towards the end of the course, the instructor discussed the use of the videos and how they were used to promote active learning. He described how the video presentation format was changed early in the semester, first to compensate for an unanticipated change in schedule, but then continued in attempt to improve the discussion portion of the lesson. During the interview in the end of the semester the instructor said, "At the beginning of the class for the first four to six weeks we would have them watch the whole video on Tuesday and then we would spend all of Thursday discussing it. About halfway through we changed that protocol for a number of reasons [mainly, as an adjustment to students' reactions], and

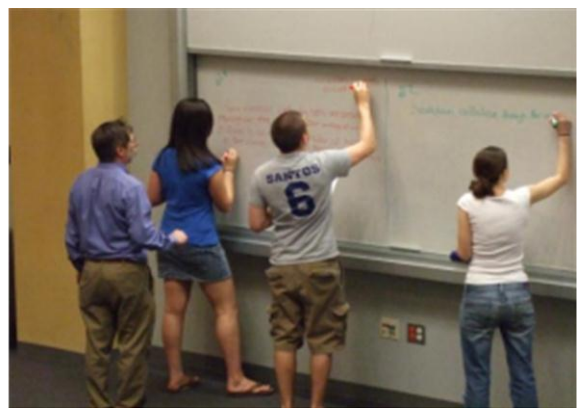

Fig 2. Small groups' representatives presenting their responses on the white board.

Table 1. Examples from the observers' notes describing the class sessions.

Teaching Methods	Observers' documentation
Active Learning	
Instructor's questions	Type of questions: a) Do you have any questions? (the instructor stopped the lecture for questions); b) "These are [The instructor pointed on the board] the kind of questions that you will see on the test, would you like a little bit of help on any one of them?" c) The instructor asked content knowledge questions while lecturing, allowing student a minute (wait time) to think about their answers.
Students' questions	The instructor encouraged students to write in-class and out of class questions. If there was not enough time for the instructor to answer all the questions immediately, he asked the student to hold the question and answer later. The instructor modeled "just-in-time" teaching (i.e., collecting students' written questions from the previous class and answered some of them in the next class session).
Multiple channels of communication	Power-point presentations, white board, video-tapes.
Group study and whole class discussions	Students were asked to answer questions within their small group, each group (4-8 students) presented their answer on the board, followed by a whole class discussion, while the instructor added information to the discussion.
Assessment	Assessments included 6 mini exams with opportunities to retake each test, modeling that science should be taught as small units with assessments following each unit, not as a summative assessment. The exams also included alternative assessment elements, such as, analysis and evaluation of scientific articles.
Clarity in Teaching	
Features of clear teaching	The instructor a) simplified explanations (using drawings and videos); b) emphasized main ideas (using repeated explanations, vocal emphasis); c) presented flexibility in teaching - adjusting teaching to students' reaction – the instructor asked the students to vote on the way that they liked to watch the films (small segments vs. large segments).
Connection to students' interest	The video tapes used examples and explanations from the students' world like, football game or pizza preparation to demonstrate terms in microbiology.
Features of interesting teaching	The instructor a) walked up and down the stairs, circulating among the students; b) used historical view (genetic diagnostics) – showing the process of scientific research; c) used humor.
Connection to everyday life and prior background knowledge	The instructor opened most of class sessions with questions such as, "Did you read about this topic in the newspaper?" and discussed the past week's "microbiology in news" with students. He also raised questions such as, "Do you know of any new diseases emerged in the past few years?" ("…Maybe you remember this from school, biology classes at 4th grade or 8th grade…)." The instructor built interconnections between previous and current sessions.
Linkages to teaching	The instructor explained the pedagogy he used and why he was using it (i.e., Why he put students into groups, why he allowed taking a test retake.)

began showing the videos on both days, stopping after each segment to discuss it."

Group study

In almost all class sessions students were asked to work on in-class assignments in groups. The small group assignments included discussions about questions provided by the instructor and then each group shared the information with the whole class. Figure 2 is representative of the small groups presenting their responses on the white board.

Assessment

When asked about assessment, the instructor shared his thoughts on his experience from a variety of perspectives. While he believed that the course was "over-assessed," he was confident that the assessments were justified and modeled good teaching practices. He felt that the assessments were designed to encourage the students to complete the reading assignments. He also expressed his feeling that assessment was another way to model good teaching practices. When queried about making the course learning-centered rather than content-centered, the instructor described his intentions and how he assessed the outcome, "What we are interested in is having them acquire the skills, and practice the skills of learning about science; in this case, science within microbiology. So that's what I mean by learning-centered not content-centered."

Clarity in Teaching

Features of clear and interesting teaching

The instructor stated that he made his teaching clear and interesting in the following manner, "…I strive to teach clearly by using examples and illustrations, in the class we make extensive use of simple illustrative diagrams, presenting a material in a simple and logical manner, repeating, stressing and summarizing important points."

Connections to everyday life

The instructor explained his intention to guide the students to an understanding of microbiology that would allow them to appreciate how it might apply to their lives and how they may keep informed through the use of popular literature. He commented, "What I am interested in is their understanding of science process and microbiology from an application standpoint. Meaning that they have an appreciation for how it fits within their world. And they have the skill and ability to read what I will refer to as lay literature; Washington Post, Discover, Science News, and be able to read it from a semi-critical fashion*."*

Linkages to Teaching

The course instructor expressed his intentions to make the course relevant to prospective teachers, especially those interns who may be considering teaching science to elementary or middle school aged learners, and to model teaching practices that could be used in those settings. He explained, "I have a particular interest in how those pre-service teachers, those students in the College of Education, the kind of science they get exposed to during their time here at the University. So within this course we model and refer back to science teaching perhaps more than you would expect to find in other comparable non-majors general education courses within the university outside of the College of Education." The instructor strived to make the course explicitly connect with teacher education. He planned to explain the pedagogy behind his teaching methods and assignments, so that the students would always be aware of the learning goals, "I make, whenever possible, explicit and transparent, the pedagogy I'm using and why I'm using it. Why we put students into groups, why we do discussions, why is it that I allow them after taking a test to retake the test in a window of time for an average of the two grades."

Students' Perspective

Students' content knowledge

The instructor collected pre and post content surveys which included identical twenty questions in three subtopics: Chemistry – 4 questions, Molecular Biology - 8 questions, and Biology - 8 questions. Twenty-one students responded to both the pre and post surveys. Encouragingly, a t-test analysis showed that students significantly ($p < 0.001$) improved their scores on the post survey in the content areas that were taught, Molecular Biology and Biology. The average score on the pre-test was 58.5% (11.7 out of 20) while the average score for the post survey was 73% (14.6 out of 20). There was no significant change in scores on the Chemistry content, which served as the control variable. Figure 3 summarizes students' scores on the three subtopics of the survey.

At the end of the semester, 25 students provided responses to a final course evaluation. The questions had an opening sentence and five different hierarchical categories. Students were asked to choose one category. To the question, "the weekly learning guide was…" 32% of the students answered "very beneficial", 36% "useful" and 32% responded "marginally useful". None of the students chose "a waste of time" or "have no opinion". One question asked about the unusual use of assessment in the course. To the statement, "The ability to retake the first two in-class test was…" 52% of the students answered "very useful in helping to understand the course material", 20% useful in helping to understand the course material and 28% responded "No opinion". None of the students chose "not useful" or "not appropriate for college course".

Another question asked students to refer to the small group discussion. To the statement, "The in-class group discussion activities were…" 16% of the students answered "very useful in helping to understand the course material", 44% useful in helping to understand the course material, 36% responded "not useful" and 4% "No opinion". None of the students chose "too simplistic". One question referred to the video tapes that were used in the class, 8% of the students answered that the videos were

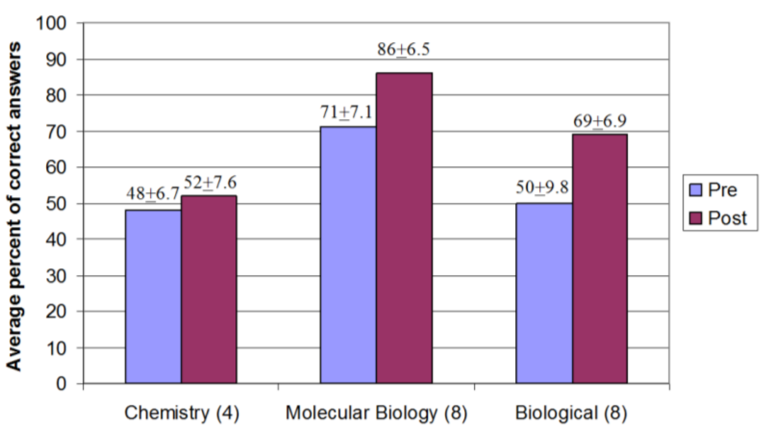

Fig. 3. Students' average percent of correct answers (± Standard Error) in the three content domains: Chemistry, Molecular Biology and Biology (n=21).

"the best part of the course", 52% answered that "they were interesting and enriching", 32% chose "of limited value" 8% chose detracted from the course. None of the students chose "they added nothing to the course". To the question, "How worthwhile was this course in helping you to understand the roles of microbes in the world?" 36% of the students answered "very", 52% "somewhat", 8% chose "a little" and 4% responded "have no opinion".

Undergraduate students' feedback and gain of content knowledge

One open-ended question in the end-of-semester course evaluation instrument applied to the connection between science and teaching. We asked only students who considering teaching science to answer the following question: *"What teaching practices/techniques did you see modeled in this course that you think would benefit your science teaching? Explain."* Seven students answered this question. Responses included: "Peer-to-peer learning, working in groups", "I would provide feedback to my students as well as facilitate discussions in lecture"; "I liked how the videos illustrated the information. It made it easier to understand certain material"; "The best way for your students to learn is if they are invested and see it done hands on"; "Relating science with everyday life".

One of the homework assignments asked students to report if they thought that the course has stimulated them to think at all about a career in teaching and if not if they feel that it helped them at all to educate other populations (like their future kids). Twenty-one students responded to this question. Twelve students reported that the course stimulated them to think about teaching career. Most of them (10) already thought about a teaching career before, but they reported that the course contributed to their teaching skills. One student commented, "…One thing this class has showed is how important it is to engage all of the senses when really trying to educate. In this class we do physical things with our hands, we listen, we watch, we read, this class really touches all bases. Even though I am going to teach English, I can still incorporate physical things into it. Also, this class has shown how a mixture of independent and group work can enhance the learning environment. Overall, I feel this class has taught me to keep things diverse in the classroom when I am teaching."

Nine students reported that the course didn't stimulate them to think of teaching career, but most of them (7) wrote that the reason for it is that they came to the course with the notion that they want to do something else in their lives. They did stress that the course helped them in different ways, "I have never wanted to be a teacher and have no desire now to be a teacher…. [But] the class did teach me how to explain things to people who are new to a subject. In this sense perhaps it will help me in my career when I am briefing interns or entry level jobs."

Two students said that they don't feel that the course contributed to their teaching abilities at all, "I don't feel that this class has necessarily made me think about my teaching. I think that a large part of this is that this course does not directly target teaching procedures. I am not overly interested in science and am planning to teach general education for grades 2 and 3 and therefore have a hard time relating microbes to my teaching. I did not learn about microbes until I was much older, at least in high school."

DISCUSSION

In this study we investigated a curricular and pedagogical innovation in an undergraduate microbiology course ("Microbes and Society") for non-majors. Generally, most science courses are content driven and re-enforce students' negative view that science is a collection of facts unrelated to their world. For non-majors who must take and pass science content courses to satisfy degree requirements, this undesired outcome is especially true. An established set of studies (e.g., Vance-Chalcraft, et al., 2007) reveal that most of these kinds of science courses that emphasize facts use a reproductive model where information is presented in didactic lectures, memorized and reproduced on assessments. Therefore, the aim of the Microbes and Society course was to improve students' understanding of science, using active learning approaches, concentrating on clarity in teaching and connecting science to teaching.

In this study we documented the instructor's perspective, and we provided his rationale and explanation for the teaching and learning approaches that he used. We reported on the notes of observations that were taken by the three science education observers. The observations supported the pedagogical claims of the instructor. He did indeed teach in the way that he planned. We reported the students' feedback to the course. A key finding was that while the course placed an emphasis on modeling good pedagogy and promoting teaching science as a career option, significant gain in science content was achieved by the students.

Our findings also suggested areas that the course could be improved. Both the researchers and the instructor thought that the course included too many assessments and the use of videotapes as an instructional strategy were too extensive. The students also shared these thoughts and recommended future changes in the course. Specifically, they recommended having more class discussions. We observed that the instructor was very flexible and attentive to the students' requests throughout the semester, and he changed his teaching accordingly. For example, mid-semester after the students made the suggestion, he began to show the videotapes in short chunks, followed by explanation and some class discussion instead of in large chunks that filled up a class session.

Our assumption was that by appreciating the unique needs and characteristics of students it will set an educational environment that would enhance enduring learning for each student. Since this course was part of a science teacher preparation project (Project Nexus), it was important to demonstrate to the education majors and others what clear teaching is and how to teach for understanding. Positively, most of the students in the course expressed that the innovative activities in the course (i.e., group discussion, the videotapes, the test retake) were useful in helping to understand the course material, something they believed would assist them in becoming better parents even if they did not decide to become teachers.

We believe that our findings showed that we implemented a non-major’s science course that enhanced students’ science understanding and increased their motivation and satisfaction. This course could serve as a model for other non-major courses.

As a postscript, for the next semester’s offering of Microbes and Society, we have recruited 32 diverse students, with 2 on the wait list. We look forward to building on what we have learned to further improve the course.

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REFERENCES

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS). 1993. *Benchmarks for Science Literacy*, Oxford University Press, New York.

ALLEN, D. AND K. TANNER. 2006. Approaches to Biology Teaching and Learning: Infusing Active Learning into the Large-enrollment Biology Class: Seven Strategies, from the Simple to Complex. *Cell Biology Education* 4: 262-268.

EBERT-MAY, D., BREWER, C. A., AND S. ALLRED. 1997. Innovation in large lectures - Teaching for active learning through inquiry. *BioScience* 47(9): 601-607.

HATIVA, N. 2000. *Teaching for Effective Learning in Higher Education.* Dordrecht, Kluwer Academic Publisher, the Netherland.

JOHNSON, D. W., JOHNSON, R., AND K. SMITH. 1998. *Active learning: Cooperation in the College Classroom.* Interaction Book Company Edina, Minn.

NATIONAL RESEARCH COUNCIL (NRC). 1996. *National Science Education Standards*. National Academy Press, Washington, DC.

NATIONAL RESEARCH COUNCIL (NRC). 2007. *Taking Science to School.* National Academies Press, Washington DC.

SALISH I RESEARCH PROJECT RESEARCH TEAM. 1997. *Secondary science and mathematics teacher preparation programs: influences on new teachers and their students.* The Final Report of the Salish I Research Project. Iowa City: University of Iowa.

SLISH, D.F. 2005. Assessment of the use of the Jigsaw Method and Active Learning in Non-majors, Introductory Biology, *Bioscene* 31 (4): 4-10.

UDOVIC, D., MORRIS, D., DICKMAN, A., POSTLETHWAIT, J., AND P. WETHERWAX. 2002. Workshop Biology: Demonstrating the effectiveness of active learning in an introductory biology course. *BioScience* 52(3): 272-281.

UNSEEN LIFE ON EARTH. http://www.learner.org/resources/series121.html., (March, 3rd, last date accessed).

VANCE-CHALCRAFT, H., BUNNELL, A., ENDERLE, P., FEWELL, M., AND T. CRENSHAW. 2007. *Re-thinking university non-majors science education: Curriculum revision for large, multiple instructor biology classes.* A paper presented at the annual meeting of the Association for Science Teacher Education (ASTE), Clearwater Beach, Florida.