The 2013 abstracts are organized by both content and pedagogy to help participants navigate more easily through the poster session. The content themes are based upon the ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education (www.asm.org/educators). The guidelines identify six overarching concepts, which provide a framework for 22 key microbiological topics, and two key skills and are based on concepts put forth in the 2011 national report, Vision and Change in Undergraduate Biology: A Call to Action. The ASM concepts and topics were selected to promote deep understanding of core concepts that are deemed to be of lasting importance beyond the classroom. Likewise, students’ development of competency in the selected skills will have enduring and lasting value beyond both the classroom and laboratories.

In May 2012, a Perspectives article published in the Journal of Microbiology & Biology Education (JMBE) entitled, “The Development of Curricular Guidelines for Introductory Microbiology that Focus on Understanding,” described the consensus-building process around the new, concept-based curriculum for Introductory Microbiology courses.

For the purposes of ASMCUE, a seventh concept, advancing STEM education and research has been added to the abstract in order to identify authors working in this broader-scoped area.

The pedagogy themes are organized into five categories: course design, hands-on projects, student learning, teaching approaches, and teaching tools.

Each abstract is assigned to both content and pedagogy themes. These assignments, designated by the submitting author, are placed below the full abstract. A quick reference index listing abstracts by content is available on p. 163, and by pedagogy on p. 164.

1-A
Using Undergraduate Research in Microbiology and Biotechnology Courses to Improve Student Engagement and Critical Thinking Skills
V.L. Balke and J.V. McDowell.
Delaware Technical Community College, Newark, DE.

ASM Curriculum Guideline Concept(s): Impact of microorganisms, Advancing STEM education and research
Pedagogical Category(ies): Course design

2-B
The Impact of a Multidisciplinary Functional Genomics Project on the Biochemistry and Molecular Biology Curriculum at Otterbein University
J.A. Bennett, C.J. Hayes, and J.T. Tansey.
Otterbein University, Westerville, OH.

ASM Curriculum Guideline Concept(s): Systems, Advancing STEM education and research
Pedagogical Category(ies): Course design
3-A Evaluating Two Teaching Strategies to Help Students Understand Complex Ecological Concepts
A.E. Bernhard.
Connecticut College, New London, CT.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches

4-B Active Learning and Advising Strategies in Introductory Biology II—If You Click It, a Few More Will Come
S.M. Boomer, M.J. Baltzley, and K.L. Latham.
Western Oregon University, Monmouth, OR.
ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning

5-A Mapping Misconceptions: An Evaluation of the Use of Concept Maps to Assess Learning Gains
S.K. Morgan and A.G. Briggs.
Beloit College, Beloit, WI.
ASM Curriculum Guideline Concept(s): Information flow, Advancing STEM education and research
Pedagogical Category(ies): Teaching tools

6-B Research-Based Laboratory Promotes Student Learning and Enhances Undergraduate Research Experience
M. Choudhary, B. Myagmarjav, C. Trahan, A. Bavishi, and L. Severin.
Sam Houston State University, Huntsville, TX.
ASM Curriculum Guideline Concept(s): Evolution, Information flow
Pedagogical Category(ies): Teaching approaches

7-A Expectations in an Introductory Science Course: Why Students Don't Study as Much as They Should
L. Clement1,2,3, D. Nathaniel1, J. Lewis1,2, B. Wong1, and E. Johnson1,2.
1City College of San Francisco, San Francisco, CA, 2Bio-Link National ATE Center in Biotechnology and Life Sciences, San Francisco, CA, 3The American Society for Cell Biology, Bethesda, MD.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning, Teaching approaches

8-B Teaching the Excitement of the Unknown in Science: Involving Students in Novel Research Questions
L.M. Cozy and S.M. Callahan.
University of Hawaii, Honolulu, HI.

ASM Curriculum Guideline Concept(s): Information flow, Advancing STEM education and research
Pedagogical Category(ies): Course design

9-A Learning More While Teaching Less: Enhancing Quantitative Knowledge in the Microbiology Curriculum
A.H. Darnell and S.B. Aley.
University of Texas at El Paso, El Paso, TX.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning

10-B Reaching for the STARS—The Impact of Fast-Track BS to PhD Programs on Student Achievement and STEM Retention
W.B. Davis, L.M. Gloss, and M. Sanchez-Lanier.
Washington State University, Pullman, WA.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning

11-A Assessing the Efficacy of Whether a Graphing Activity in Which Students Connect Biological Concepts to Themselves in a Biology of Women Course Improves Student Learning and Knowledge Retention
C.A. DeBoy.
Trinity Washington University, Washington, DC.

ASM Curriculum Guideline Concept(s): Information flow, Systems
Pedagogical Category(ies): Student learning

12-B An Integration Approach to Increase Community and Scientific Reasoning Skills
B.M. Dewsbury, M.K. Lowenstein, and O.I. Weeks.
Florida International University, Miami, FL.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches
13-A
A Sustained University and K–12 Educator Professional Development Partnership Enhancing Knowledge, Confidence, and Skills for Active Classroom Inquiry
G. Fletcher, K.D. Moulton, V.M. Serio, Jr., A. Hatch, M. Movassaghi, A.-K. Ng, and S.M. Duboise. University of Southern Maine, Portland, ME.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Hands-on projects

14-B
Do iPads and/or Challenge-Based Learning Affect the Level of Achievement in a Biochemistry Capstone Course?
S.E. Gabriel and G.L. Stock-Kupperman. Viterbo University, La Crosse, WI.

ASM Curriculum Guideline Concept(s): Systems, Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches

15-A
A Freshman Seminar Course on the History of Antibiotic Therapy Improves Scientific and Information Literacy
M.J. Hanophy and L. Kehoe. St. Joseph’s College, Brooklyn, NY.

ASM Curriculum Guideline Concept(s): Impact of microorganisms
Pedagogical Category(ies): Course design

16-B
Teaching Research Laboratory Skills to Community College Students within the Framework of Phage Hunting
M.L. Burleson, R.H. Hale, and L.E. Hughes. University of North Texas, Denton, TX.

ASM Curriculum Guideline Concept(s): Impact of microorganisms, Advancing STEM education and research
Pedagogical Category(ies): Hands-on projects

17-A
Design and Initial Implementation of a Vertically Integrated Biology Curriculum Incorporating Inquiry-Based Modules
K. Hung, G.A. Bulla, T.C. Canam, R.E. Colombo, S.J. Meiners, M.A. Menze, and J.M. Novak. Eastern Illinois University, Charleston, IL.

ASM Curriculum Guideline Concept(s): Structure and function
Pedagogical Category(ies): Hands-on projects, Teaching approaches
22-B
Stepping Back to Go Forward: Using Progressive Clinical Cases to Enhance Understanding of Neuroendocrine Concepts
L.J. Mauro and A. Contreras.
University of Minnesota, St. Paul, MN.

ASM Curriculum Guideline Concept(s): Systems
Pedagogical Category(ies): Teaching approaches

23-A
Redesign of Multi-Section Introductory Laboratory Classes to Incorporate an Authentic Research Project in Comparative Genomics
D.M. Warner, L.E. Hake, and C.M. O'Connor.
Boston College, Chestnut Hill, MA.

ASM Curriculum Guideline Concept(s): Evolution, Pathways
Pedagogical Category(ies): Course design

24-B
Using the Research-Based High School “Discover the Microbes Within: The Wolbachia Project!” in the College Classroom
G.T. May and J.P. Odden.
Metropolitan State University of Denver, Denver, CO.

ASM Curriculum Guideline Concept(s): Impact of microorganisms
Pedagogical Category(ies): Hands-on projects

25-A
Undergraduate and Graduate Students’ Perception of Virtual Education
J. Ortellado-Canese1,2, J. Canese1, and A. Galeano2.
1Universidad Nacional de Asuncion, Asuncion, Paraguay, 2Universidad Catolica de Asuncion, Asuncion, Paraguay.

ASM Curriculum Guideline Concept(s): Impact of microorganisms
Pedagogical Category(ies): Course design, Teaching tools

26-B
Use of an Immunology-Based CREATE Module Improves Student Understanding of the Interconnectedness of the Immune System
H.R. Pelzel.
University of Wisconsin - Whitewater, Whitewater, WI.

ASM Curriculum Guideline Concept(s): Systems, Advancing STEM education and research
Pedagogical Category(ies): Teaching tools

27-A
Implementing Vision and Change: Bringing Undergraduate Research to a Non-Research Biology Program through BioSOLVE Courses and Application-Based Service Learning (ABSL) Pedagogy
G.E. Rowe.
La Roche College, Pittsburgh, PA.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches

28-B
Mixed-Methods Assessment Approach Reveals Learning Gains for Research Immersion Lab in Virology
E.R. Sanders, J. Moberg-Parker, C. Shapiro, C. Ayon, S. Toma, and M. Levis-Fitzgerald.
University of California, Los Angeles, Los Angeles, CA.

ASM Curriculum Guideline Concept(s): Impact of microorganisms, Advancing STEM education and research
Pedagogical Category(ies): Student learning

29-A
Team-Based Learning Enhances Course Content Retention in a Hybrid Classroom
H.M. Seitz.
Johnson County Community College, Overland Park, KS.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches

30-B
Course-Based Research is Effective in Engaging Students in ‘Real’ Science: Soil Bacterial Diversity Research in an Undergraduate Microbiology Course
A. Shanmuganathan.
Washington & Jefferson College, Washington, PA.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Hands-on projects

31-A
Assessment of a Novel Group-Centered Testing Schema in an Upper-Level Undergraduate Molecular Biotechnology Course
M.C. Srougi1, H.B. Miller2, D.S. Witherow, and S. Carson.
1North Carolina State University, Raleigh, NC, 2High Point University, High Point, NC, 3University of Tampa, Tampa, FL.
ASM Curriculum Guideline Concept(s): Advancing STEM education and research  
Pedagogical Category(ies): Course design, Student learning

32-B  
Students’ Behaviors and Attitudes In a Problem-Solving Exercise Leading to an Oral Mini-Test  
W.J. Staddon.  
Eastern Kentucky University, Richmond, KY.

ASM Curriculum Guideline Concept(s): Pathways, Information flow  
Pedagogical Category(ies): Teaching approaches

33-A  
Metacognitive Regulation Training to Improve Student Performance in Introductory Biology  
J.D. Stanton and T.C. Byington.  
Washington State University, Pullman, WA.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research  
Pedagogical Category(ies): Student learning

34-B  
Cooperative Assessment of Common Microbiology Student Misconceptions about Antibiotic Resistance  
A.M. Stevens¹, G. Marbach-Ad², and A.C. Smith³.  
¹Virginia Tech, Blacksburg, VA, ²University of Maryland, College Park, MD.

ASM Curriculum Guideline Concept(s): Evolution, Structure and function  
Pedagogical Category(ies): Student learning

35-A  
Refining Undergraduates’ Focus on Microscopy in the General Microbiology Lab  
S.C. Wagner and J. Taylor.  
Stephen F. Austin State University, Nacogdoches, TX.

ASM Curriculum Guideline Concept(s): Structure and function, Advancing STEM education and research  
Pedagogical Category(ies): Hands-on projects

36-B  
Microbiology Outreach in an AP Biology Classroom Using Undergraduates as Facilitators Increases High School Student Knowledge and Appreciation for Microbiology Topics  
A.H. Williams, C.R. Wood, D.K. Palamittam, S.E. Mathis, N.M. Jawahir, and A.R. Grotton.  
University of Tampa, Tampa, FL.

ASM Curriculum Guideline Concept(s): Impact of microorganisms, Advancing STEM education and research  
Pedagogical Category(ies): Hands-on projects

I-A  
Using Undergraduate Research in Microbiology and Biotechnology Courses to Improve Student Engagement and Critical Thinking Skills.  
V.L. Balke and J.V. McDowell. Delaware Technical Community College, Newark, DE.

Delaware Technical Community College (DTCC) is one of the pilot schools involved in the Community College Undergraduate Research Initiative (CCURI) which is responding to the call for reform of undergraduate science education. The major tenet of this initiative is to engage students early in their course of study by embedding undergraduate research into the curriculum. At DTCC this is accomplished by incorporating research-based laboratories, case studies, and problem-based learning activities in the microbiology and biotechnology classrooms. In the microbiology course, a custom in-house laboratory manual with accompanying technique PowerPoint and pre-lab quizzes was developed with a focus on culture-dependent analysis of microbial communities in soil. Several case studies, problem-based learning, and primary literature activities related to the research were used throughout the semester. As part of the integrated research project, students in a linked biotechnology course furthered the soil microbe research by analyzing the same soil samples in a culture-independent analysis. In addition, students were provided with the opportunity to continue research by enrolling in DTCC research courses in the academic school year and summer which also connects students with the scientists at local universities. To collate the student-generated data, DTCC Computer and Information Science students are developing a database for use by microbiology students to develop hypotheses and query the relationships between soil conditions and microbial communities. Our hypothesis is that students who are participating in research-based classroom activities will be more engaged and have improved critical thinking skills. In Spring 2011, the use of the CAT instrument developed by Tennessee Tech University was piloted in a small study (N = 16) to measure gains in critical thinking. The instrument was administered at the beginning and end of the semester to a microbiology class. The CAT total score increased from 17.13 to 19.44 with significant gains made in 3 out of 15 skills assessed (p < 0.05). The CAT instrument is being used to monitor gains in critical thinking skills as students move through their program of study and engage in undergraduate research.
4-B
The Impact of a Multidisciplinary Functional Genomics Project on the Biochemistry and Molecular Biology Curriculum at Otterbein University
J.A. Bennett, C.J. Hayes, and J.T. Tansey. Otterbein University, Westerville, OH.

An interdisciplinary study examining the roles of c-di-GMP and its associated phosphodiesterases with respect to gene expression, cell signaling, and enzyme kinetics was incorporated into multiple courses in Otterbein University’s Biochemistry and Molecular Biology (BMB) program. Undergraduate science classes often appear to students to be detached from one another; this inquiry-based project was intended to demonstrate the interplay between multiple disciplines and to provide a research experience within the Otterbein BMB curriculum. Several aspects of this project were launched in the 2012-2013 academic year. In Physical Chemistry I, cyclic di-GMP phosphodiesterase activities in crude lysates from wild-type, heat-inactivated wild-type, and mutant cells were examined and quantified via kinetic assays. In Microbial Genetics, a three week intensive course offered during the January term, students completed a mini-project using the same wild-type and mutant cells. In this project, students examined potential targets of c-di-GMP signaling through semi-quantitative PCR. Students wrote formal lab reports and made short presentations of their project. Student learning was assessed primarily via pre- and post-lab surveys; pertinent questions on pre-lab assignments and subsequent exams were also evaluated. In the Spring 2013 Cell Biology and Biochemistry 2 labs, students will also participate in this process. Preliminary data indicate that students demonstrated an increased understanding of content-based objectives (for instance, enzyme specificity and kinetic experiment design in Physical Chemistry) following relevant labwork and class projects. Students across multiple classes reported that the project increased their understanding of the scientific process and their awareness of the multidisciplinarity of the research questions involved. This interdisciplinary project will be refined for future offerings of BMB courses.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches

3-A
Evaluating Two Teaching Strategies to Help Students Understand Complex Ecological Concepts
A.E. Bernhard. Connecticut College, New London, CT.

Innovative assignments that engage students and, hopefully, lead to more significant learning have gained much attention in science pedagogy recently. I investigated whether these kinds of assignments lead students to develop better skills and, more importantly, to understand complex concepts better than more traditional types of assignments. The question addressed by this study was: do graph interpretation and data analysis assignments help students understand core ecological concepts better than traditional types of homework? Forty-three students in an introductory ecology course at Connecticut College participated in the study. Ten concepts were divided between the two types of assignments, with an effort to pair similar types of concepts. One concept in each pair was assigned to traditional types of homework consisting of a short reading assignment followed by 2–3 questions about the reading. The other concept in each pair was assigned to homework that consisted of a short reading assignment and interpretation and analysis of data that reflected the concept. Student understanding was assessed by performance on exam questions during the semester. Exam questions included multiple choice, short answer and data analysis or problem-solving questions. When results from all exam questions were combined, there was no significant difference on performance between concepts taught by traditional homework and concepts taught by data analysis homework assignments. However, when short answer and data analysis exam questions were analyzed separately from multiple-choice exam questions, students did significantly better (p < 0.01) on concepts taught by data analysis homework compared to concepts taught by traditional methods. These data suggest that different types of homework assignments help students develop different skills, but it is not clear that these skills translate to better understanding of ecological concepts.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Teaching approaches
scores or grade distributions compared to Active Learning cohorts. Active Learning and Clicker cohorts showed similar attendance patterns during the first half of the term (89% attendance); however, during the second half of the term, Clicker cohorts showed slightly higher attendance (85%) than Active Learning cohorts (76%). While attendance appeared to increase, students were only able to correctly answer about 50% of Clicker questions, suggesting that they were not considering Clicker feedback in a way that translated to improved study or exam performance. Finally, we will describe pre-course advising efforts, including the ongoing development of a predictive “pretest” (scores were significantly correlated with final course grades, regression analysis, p < 0.0001, R-squared = 0.39).

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Student learning

### 5-A Mapping Misconceptions: An Evaluation of the Use of Concept Maps to Assess Learning Gains

S.K. Morgan and A.G. Briggs. Beloit College, Beloit, WI.

The goal of the present study was to analyze the use of concept maps to gauge student understanding of the Central Dogma of Molecular Biology. Despite recent efforts to focus biology curricula on such fundamental concepts as the Central Dogma, anecdotal evidence among educators, as well as data from the education literature, indicate that students retain many misconceptions about the Central Dogma. Concept maps challenge students to assimilate new concepts into existing knowledge frameworks, and thus require higher levels of cognitive understanding such as the ability to synthesize new information. The hypothesis guiding this study is that student performance on concept maps reveals misconceptions that are missed by multiple-choice tests. Our prediction was that in an intermediate-level genetics course, students would show significant learning gains on a concept inventory but would not show significant improvement on a concept map because their retained misconceptions would only be apparent when higher levels of understanding are tested. Students enrolled in two sections of a genetics course at Beloit College, taught concurrently by the same instructor, completed two pre- and post-course assessments: 1) Central Dogma concept maps and 2) the Genetics Concept Assessment (Smith et al., 2008). Thirty-three student scores (out of 42 students) were analyzed, and statistically significant learning gains were revealed using any one of three different measures: concept inventory (student’s paired t-test p < 0.005), concept map (p < 0.00005), or increase in number of concept map connections (p = 0.02). However, analyses of variance indicated no dependence of the change in score on the concept inventory and either 1) the change in score on the concept map (F1,31 = 0.1, p = 0.77) or 2) the change in the number of connections made on the concept map (F1,31 = 0.1, p = 0.73). These results indicate that these two assessment methods may be measuring different levels of understanding and addressing different types of misconceptions. Therefore, care must be taken when interpreting evidence of student learning gains when only a single assessment method is used.

**ASM Curriculum Guideline Concept(s):** Information flow, Advancing STEM education and research  
**Pedagogical Category(ies):** Teaching tools

### 6-B Research-Based Laboratory Promotes Student Learning and Enhances Undergraduate Research Experience

M. Choudhary, B. Myagmarjav, C. Trahan, A. Bavishi, and L. Severin. Sam Houston State University, Huntsville, TX.

In recent years, different approaches and interventions have been applied to undergraduate laboratories intended to increase students’ learning outcomes. The objective of the current study was to assess the impact of a research-based approach upon student learning in a genetics laboratory. Two hypotheses were tested: first, a research-based laboratory will promote student learning, and second, it will provide students with the necessary skill sets to carry out independent research studies. A total of 160 students participated over a three-semester period, and the study was carried out with approval from the Institutional Review Board. The test instrument consisted of collaborative and critical-thinking questions dealing with principles of molecular genetics. Pretest and posttest scores were then compared to assess student learning and overall gain of knowledge. Data were analyzed using paired t-tests at the significance level of p < 0.01. Data for each individual semester displayed similar trends, and therefore analysis was performed as one integrated study. Results revealed that for all but three questions the number of correct responses significantly increased. The average posttest score significantly increased (35.58 ± 4.21) when compared to the average pretest score (20.25 ± 1.86). Also, scores for both collaborative-learning and critical-thinking type questions significantly increased. However, the learning gains were not significantly different between male and female groups. These results validate that a research-based approach broadens not only students’ learning skills but also their understanding of concepts. Furthermore, the number of students enrolled in independent research studies increased over the three semesters this study was conducted. A majority of the students enrolled in independent research studies comes from the cohort with prior research-based lab experience. As such, this study validated our hypotheses that a research-based laboratory both promotes student learning and enhances undergraduate research experience, and thus can be applied to a number of other biology courses.
ASM Curriculum Guideline Concept(s): Evolution, Information flow  
Pedagogical Category(ies): Teaching approaches

7-A  
Expectations in an Introductory Science Course: Why Students Don’t Study as Much as They Should  
L. Clement1,2,3, D. Nathaniel1, L. Lewis1,2, B. Wong1, E. Johnson1,2. 1City College of San Francisco, San Francisco, CA, 2Bio-Link National ATE Center in Biotechnology and Life Sciences, San Francisco, CA, 3The American Society for Cell Biology, Bethesda, MD.

This study explores the metacognitive and motivational issues faced by students in an introductory chemistry course at a large, urban community college. We asked whether students’ understanding of course expectations were aligned with their instructors’. We also asked if self-reports of poor study habits correlated with lower metacognitive abilities in students. To do this, we surveyed 110 students enrolled in 5 sections of a 4-unit, 7-hours-a-week lecture/lab prerequisite course for the university-transferable general chemistry sequence.

We found a discrepancy between instructors’ estimates of required study time for this course (12–15 h/w), students’ estimates (only 37% of students thought they should study over 7 h/w to be successful), students’ availability (only 26% were available for more than 7 h/w) and students’ actual study time (only 7% actually studied this long).

Among students who did not feel they studied enough, 32% indicated job and/or family responsibilities as the sole reason for not studying and 22% said they simply could not focus on their work.

To find out what kept students from focusing on their work, we used the Motivated Strategies for Learning Questionnaire (MSLQ) to assess motivation and learning strategies. Students who felt they had enough time to study (G1, n = 24) had similar MSLQ scores to students who indicated job and/or family responsibilities as the sole reason(s) for not studying enough (G2, n = 26). However, students who indicated they could not focus as the sole reason (G3, n = 16) had significantly lower scores in 4 of the 5 categories for cognitive and metacognitive strategies, including rehearsal (G1 vs. G3, p = 0.021; G2 vs. G3, p = 0.003), elaboration (p = 0.01, p = 0.02), organization (p = 0.0147, p = 0.0017), and metacognitive self-regulation (p = 0.0004, p = 0.0003). In terms of motivation, they also scored lower on task value (p = 0.003, p = 0.003).

Together, these results indicate that community college freshmen may not be fully aware of the expectations of an introductory science course, and that a portion of them may lack the learning strategies required to study adequately for such a course.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research

Pedagogical Category(ies): Student learning, Teaching approaches

8-B  
Teaching the Excitement of the Unknown in Science: Involving Students in Novel Research Questions  
L.M. Cozy and S.M. Callahan. University of Hawaii, Honolulu, HI.

Senior level microbiology students often desire primary research experience. However, opportunities for research can be limited. We hypothesized that integration of experimental questions from research lab programs into teaching lab programs may provide experience with primary research as well as improve student understanding of microbiological concepts beyond the limits of pre-prepared lab assignments. To test this, the senior-level bacterial genetics lab course, M475L, at the University of Hawaii, was designed to approximate the experience of doing post-graduate-level novel research. Course evaluations were then compared to M461L, Immunology, which was also taught Fall semester, but did not use research in its teaching exercises.

During Fall semester, 2012, a class of 15 students conducted two semester-long experiments addressing unanswered research questions about an unusual model system: the cyanobacterium Anabaena. Students performed a novel forward genetic screen by transposon mutagenesis. A semester-long draft writing process was paired with critical reading of primary literature and culminated in the creation of a journal style manuscript about the second experiment. To assess learning from this course design, students were given a 4-item assessment covering course learning goals in microbial genetics at both the beginning and the end of the semester as well as a course evaluation survey.

Evaluation surveys showed that attitudes toward the research-based course design were overwhelmingly positive. 100% of students “agreed” or “strongly agreed” that they gained a good understanding of concepts/principles in this field compared to 72% for the comparison group. In addition, the proportion of M475L students answering the pre-/posttest questions correctly increased for each question over the semester. A pre-/posttest was not administered to the comparison group. We conclude that integrating novel research into teaching labs can be an effective method for conveying concepts, providing primary research experience, and helping spark enthusiasm for microbiology in general.

ASM Curriculum Guideline Concept(s): Information flow, Advancing STEM education and research  
Pedagogical Category(ies): Course design

9-A  
Learning More While Teaching Less: Enhancing Quantitative Knowledge in the Microbiology Curriculum
Meeting students at their level of preparation and graduating them with fewer credit hours, as mandated by the state of Texas, compounded the difficulty of instilling in students core concepts and competencies defined in the 2011 Vision and Change report. A major overhaul of the undergraduate microbiology curricula was necessary to meet these challenges and convince students to master additional content, regardless of their level of preparation. Support by the National Institutes of Health permitted testing the hypothesis that revamped and newly created courses integrating biological modeling, computational knowledge, statistical analysis, and data analysis would result in increased understanding of relevance, thus resulting in higher graduation rates. Beginning with the first introductory biology lab, students were required to run experiments, use a calculator and computer to analyze and model data, and then write up and present their results. The math requirement also changed from two statistics courses to one, where generating and analyzing statistics in team biology projects presented to the class of biology majors was the final project. To assess student learning, we focused on student performance indicators such as retention in major, success in subsequent courses, graduation numbers, and continuation to graduate and professional programs. We also collected attitudinal surveys. Results of these curricular modifications show that over a six year period between Fall 2006 and Fall 2012, the number of biological science students has nearly tripled at the University of Texas at El Paso, with the percentage of underrepresented minorities, primarily Hispanic, rising 10% (to over 85%). Assessing degree output six years prior, the six-year graduation rate has risen from 78% to 85% over a six-year timeframe. If we only maintain our current 85% graduation rate of biological science students, by 2018 we should see more than 1,200 students, 85% of whom are Hispanic, entering the workforce or continuing at the graduate level prepared to critically address not only biology-related problems but complex interdisciplinary issues.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning

10-B
Reaching for the STARS—The Impact of Fast-Track BS to PhD Programs on Student Achievement and STEM Retention
W.B. Davis, L.M. Gloss, and M. Sanchez-Lanier. Washington State University, Pullman, WA.

Retention of students in STEM is a critical problem at U.S. universities since only 60% of STEM majors earn a degree. The recent report “Engage to Excel” identified intellectual engagement and achievement, motivation, and identification in the field as factors strongly linked to student persistence in STEM. A best practice to enhance student retention is early and sustained engagement in mentored undergraduate research. Five years ago, SMB initiated the Students Targeted towards Advanced Research Studies (STARS) program, a research fast-track designed to allow students to complete their baccalaureate and Ph.D. education in as little as seven years. The program identifies promising freshmen pursuing a research career and engages them in research through a first semester introduction to research course and a series of research rotations over their first three years. An innovative foundation of the STARS program is a culture of intensive mentoring that includes an annual assessment of student progress by the entire SMB faculty. Our hypothesis was that a research and mentoring intensive program like STARS would lead to significant gains in student persistence in the Molecular Biosciences, and an increase in student matriculation to graduate programs. Assessment of our first 15 students shows that STARS has positive impacts on student retention with all enrolled STARS students persisting in SMB, as compared to a departmental 62% retention rate for other certified majors and an overall 77% STEM completion rate (2008 and 2009 certified majors; 164 students). STARS students complete their BS degree in an average of 3.6 years, as compared to 4.3 years for other students, indicating that they effectively balance their intensive research experience and academic obligations. Out of the first 7 STARS students who earned their bachelor’s degree, 86% are in Ph.D. programs (5 SMB; 1 Stanford); in comparison, only 14% of non-STARS students entered graduate programs even though 47% of these students participated in at least one semester of mentored undergraduate research. In summary, the STARS experiment is proving to be successful.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning

11-A
Assessing the Efficacy of Whether a Graphing Activity in Which Students Connect Biological Concepts to Themselves in a Biology of Women Course Improves Student Learning and Knowledge Retention
C.A. DeBoy. Trinity Washington University, Washington, DC.

Biology of Women is a capstone course for majors and nonmajors designed to bridge GenEd courses with major courses at the all-women’s college within Trinity Washington University. For this course, a pilot study was conducted to investigate whether learning outcomes improve when students participate in an activity in which they connect concepts to themselves. In Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses, Dee Fink explains that a “taxonomy of significant
learning” includes “caring, human dimension, and integration.” My hypothesis is that incorporating these components into an activity in which students create a graph based on data they collect from themselves will improve learning about hormonal regulation of the reproductive cycle. For this activity, students first predicted physiological effects from existing graphs of abnormal hormone levels. Students graphed their own basal body temperatures throughout their reproductive cycles and graphically predicted accompanying physiological changes. The efficacy of this activity was measured by averaging the percentage of students correctly answering relevant questions after the topic was introduced by lecture (48%), after the activity (84%; p < 0.05), and in the final quiz (84%). In comparison, for an objective on diseases of women taught with a combination of lecture, case study, and discussion, averages of 86% and 89% of students correctly answered questions on in-semester and final quizzes, respectively. In contrast, when pedagogy included only lecture for a genetics objective, the percentage of students answering a question correctly on an in-semester quiz, 71%, decreased to 29% on the final quiz. In conclusion, after completing the graphing activity, the average percentage of students correctly answering questions about reproductive cycle hormones significantly increased. This suggests the activity was effective, although not more than other engaging pedagogies encouraging active learning. Comparison of data from lecture-only vs. graphing self-data pedagogies shows that the latter may improve retention of knowledge.

**ASM Curriculum Guideline Concept(s):** Information flow, Systems

**Pedagogical Category(ies):** Student learning

### 12-B

**An Integration Approach to Increase Community and Scientific Reasoning Skills**

B.M. Dewsbury, M.K. Lowenstein, and O.I. Weeks. Florida International University, Miami, FL.

At Florida International University (FIU), we have an NIH-funded program called QBIC (Quantifying Biology In the Classroom), whose mission is to improve the pedagogical approaches used in our department for teaching biology concepts. Central to our new approach is a strategy we call the Teaching Pentagon. The Teaching Pentagon uses five classes to integrate concepts and student learning approaches to maximize retention of the material and to immediately contextualize the subject with real-world applications. The classes are separate but the syllabi are linked such that the student is exposed to the same concept in different ways every single week. We have been using this approach for three years and recently completed an assessment that sought to address our hypothesis that this integrative approach both improves concept retention and the sense of community among our students. Compared to a control group QBIC students performed better on tests of scientific reasoning (Lawson test) and reported a greater sense of community (CLASS). The QBIC students were not significantly different than the control group on their knowledge of biology concepts (BCI test). Our results suggest that our teaching strategy is successful at increasing above-knowledge traits and affect behaviors both of which may have positive consequences for pre-professional school standardized examinations.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research

**Pedagogical Category(ies):** Teaching approaches

### 13-A

**A Sustained University and K–12 Educator Professional Development Partnership Enhancing Knowledge, Confidence, and Skills for Active Classroom Inquiry**

G. Fletcher, K.D. Moulton, V.M. Serio, Jr., A. Hatch, M. Movassaghi, A.-K. Ng, and S.M. Duboise. University of Southern Maine, Portland, ME.

“Micro- and Nano-space Explorations of Health and Disease,” the NIH-sponsored Science Education Partnership Award (SEPA) project at the University of Southern Maine (USM) has established a sustained learning network of scientists and K–12 teachers engaged in content workshops and microbiology, microscopy, and nanotechnology laboratory experiences. We hypothesize that the experiences will inspire increased active micro- and nano-scale classroom observation and inquiry.

USM faculty and staff involved in the SEPA program in the USM Department of Applied Medical Sciences provide learning opportunities in the form of readings, group discussions, microscopy, and molecular microbiology laboratory activities to enhance content knowledge applicable to the biology curriculum as part of the university’s engagement with the community.

Seventy-eight teachers have participated (20 in more than one program) in 2–3-week summer workshops and/or 4–12-week fall and spring Saturday programs. Overall, SEPA professional development programs at USM have provided light microscopes equipped with digital cameras, and training in their use, to 48 grade 3–8 teachers in three 2-week summer workshops and bioscience content in five fall and four spring semester Saturday morning workshops, including on some occasions laboratory isolation of bacteriophages followed by TEM imaging, and molecular biological studies of the phage genomes.

Conclusion: Success was measured by a 16–18% improvement on posttests over pretests, teacher comments regarding their own increased emphasis on microscopy in the classroom, improved student interest in the variety of samples viewed, teacher comfort in adding the microbial world to their curriculum, and universal peer-recommendation of the programs. Classroom inquiry has also been actively
reinforced and supported through outreach of project staff providing resources such as portable fluorescence imaging and scanning electron microscopy.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research

Pedagogical Category(ies): Hands-on projects

14-B
Do iPads and/or Challenge-Based Learning Affect the Level of Achievement in a Biochemistry Capstone Course?
S.E. Gabriel and G.L. Stock-Kupperman. Viterbo University, La Crosse, WI.

In 2011, Advanced Biochemistry, a senior capstone course for biochemistry majors, was first offered. The course objectives focused on students’ ability to access and use primary literature. Despite engaging conversation and excellent student presentations, course evaluations were lower than usual (3.65/5 compared to 4.3/5 from my previous semester). Notwithstanding, the evaluation of the instructor was equivalent to historical results. In an effort to improve the course, in 2012 a challenge based learning (CBL) design was used by framing the course around four big questions relevant to our local community and world. In addition to this change, iPads were introduced halfway through the semester. These changes were made to test two interrelated hypotheses: first, that a CBL course design would increase students’ engagement in the course and therefore their achievement of learning outcomes and, second, that the use of technology in this design (iPads) would increase student connectivity and result in a further increase in achievement and course satisfaction. To test these hypotheses, after IRB approval, student surveys were administered by a third party three times throughout the semester and course artifacts were collected and graded by several different faculty. These data show a clear improvement in students’ perception and, to a lesser degree, achievement in the course. Most significantly, course evaluation results increased when compared to the previous year (4.5/5 as compared to 3.65/5 in 2011). Students also rated the CBL approach as highly effective in achieving core course outcomes and related skills (all queried outcomes averaged 4.2/5 at midterm). With the addition of iPads at the midterm, only a marginal gain was observed in the CBL assessment data by the end of the term (from 4.2/5 to 4.45/5). With regard to achievement, while iPads did not increase mastery of course learning objectives as measured by their cumulative graded work (without iPads averaged 90.2% while with iPads averaged 88.6%), student surveys and comments note the devices increased their time spent on class related material and their self-reported learning in the course.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research

Pedagogical Category(ies): Teaching approaches

15-A
A Freshman Seminar Course on the History of Antibiotic Therapy Improves Scientific and Information Literacy
M.J. Hanophy and L. Kehoe. St. Joseph’s College, Brooklyn, NY.

As part of its 2011 Core Curriculum revision, St. Joseph’s College created a new freshman seminar course meant to offer a laboratory experience of careful and critical reading, writing to learn, research skills, and cooperative classroom activities. Individual course sections were to focus on a unique and engaging topic related to the discipline of the instructor which would help students develop the pivotal learning skills necessary for academic success including the requisite information literacy necessary for college-level research.

One of these courses, “Magic Bullet, Miracle Drug: The History of Antibiotic Therapy,” was designed to consider the discovery and subsequent development of antimicrobial therapies, the way in which the introduction of these drugs influenced society and medicine, and modern day concerns about the spread of antibiotic resistance. Through the development of appropriate research skills and utilizing a variety of resources, students were to investigate the important role that antimicrobial compounds have played in the treatment and control of human infectious disease and to examine the history of antibiotic discovery and development.

It was hypothesized that the “Magic Bullet” course would not only achieve the general objectives of the freshman seminar by improving information literacy and research skills but would also improve scientific literacy and student knowledge of the scientific process. Pre- and posttesting of students by library faculty and by the course instructor indicated that students did in fact show significant progress in all areas including improved scientific literacy. A subsequent survey of students involved in the “Magic Bullet” class indicated that they had found the specific course content as effective a means of developing research, critical reading, and writing skills as any other course they had taken during their first semester of college.

ASM Curriculum Guideline Concept(s): Impact of microorganisms

Pedagogical Category(ies): Course design

16-B
Teaching Research Laboratory Skills to Community College Students within the Framework of Phage Hunting
M.L. Burleson, R.H. Hale, and L.E. Hughes. University of North Texas, Denton, TX.
The University of North Texas-Howard Hughes Medical Institute (UNT-HHMI) Transitions Summer Workshop (TSW) provides students in the life sciences who have completed the first year of community college with the opportunity to learn academic success skills and receive an introduction to research methods. Up to 16 students have participated in this program each of the previous two summers. The goal of this program is to teach students a suite of research laboratory skills that have broad-based applications across most sub-disciplines of biology in an effort to foster careers in research. Our hypothesis was that, to engage students in learning laboratory skills, we should provide the laboratory experience and research methodology skills within the context of a research project. Therefore, the laboratory activities were organized within the framework of the successful Phage Hunters Advancing Genomics and Evolutionary Science (PHAGES) program of Graham Hatfull and the HHMI Science Education Alliance. While isolation of a bacteriophage remains a desired outcome, the primary expectation is for students to develop laboratory skills such as use of standard laboratory equipment, preparation of microbiological growth media and chemical solutions, and management of data. Program evaluation included collection of pre- and postexperience data on a modified version of the Summer Undergraduate Research Experience (SURE) and Classroom Undergraduate Research Experience (CURE) surveys, as well as a follow-up survey later in the academic year. When asked on the presurvey what they expected to learn in the program, laboratory skills was cited by the majority of students. On the postsurvey, the laboratory experiments were indicated as the most cited “best aspect” of the program. Laboratory techniques was also rated 4.92 on a 5 point scale (5 = very large amount) of self-reported learning on the follow-up survey. As well, participants successfully isolated 7 mycobacteriophages (2011) and 7 Streptomyces phages (2012) during the program. The results demonstrate that the TSW program is successfully using a phage hunting framework to provide community college students with essential research laboratory skills.

**ASM Curriculum Guideline Concept(s):** Impact of microorganisms, Advancing STEM education and research

**Pedagogical Category(ies):** Hands-on projects

### 18-B

**Use of MasteringMicrobiology Online Resources to Implement “Learn Before Lecture” Strategy: A Comparative Analysis of Student Learning**

**A.S. Kucknoor.** Lamar University, Beaumont, TX.

In large traditional classrooms of over 200 students, students are introduced to the content of subject material through the delivery of lecture. Using “hands-on” activity-based learning can be a challenging task in a large microbiology class. Students coming to class with no prior knowledge of what to expect in class has led to poor student learning. To address this issue, a student-friendly online MasteringMicrobiology textbook website was used to test the hypothesis that if the students were introduced to the material prior to lecture, their learning and overall performance in the course would improve. The study used the online set-up of prelecture homework on each chapter followed by a postlecture quiz on the same content a few
days after the lecture. The homework included interactive tutorials, end-of-chapter critical thinking questions, and animations. A deadline was assigned for both the pre- and postlecture quizzes, and a total of 25 sets of quizzes were used for the entire semester, which was credited for 5% of the total grade. Based on the comparison of overall grades from 2011 (without MasteringMicrobiology) and 2012 (with MasteringMicrobiology), an analysis of student final course grades showed that those students who did better on their MasteringMicrobiology homework also performed better in the course. 85% of the students who earned an A in the course had also earned a score of over 90% on MasteringMicrobiology assignments. Those students who did not pass the class averaged a score of about 35%. Also the amount of time they spent on MasteringMicrobiology was lower than those that made an A, B, or C grade. In addition, the overall number of students receiving A or B grades increased significantly during the three semesters in 2012 when MasteringMicrobiology online resources were included, compared with the three semesters with no MasteringMicrobiology in 2011. The data suggest that MasteringMicrobiology can predict a student’s success based on the effort that student puts into the MasteringMicrobiology homework. If a student completes the homework consistently, his or her homework scores and final grade will reflect the effort.

ASM Curriculum Guideline Concept(s): Structure and function, Impact of microorganisms
Pedagogical Category(ies): Student learning, Teaching tools

19-A
Take-Home Active-Learning Exercises may Result in Learning Gains Equivalent to In-Class Active Learning, with Both Superior to Traditional, Low-Structured Lecture in Introductory Biology
K.A. Lennon1 and D.P. Puthoff2. 1Hagerstown Community College, Hagerstown, MD, 2Frostburg State University, Frostburg, MD.

Recent studies report failure rates from 30% to 56% in undergraduate introductory biology (Freeman et al., 2011), and that in-class active learning dramatically improves student success (for example Crossgrove & Curran, 2008; Freeman et al., 2007, 2011). One of the problems with implementing active learning is faculty resistance to a perceived increased workload. We asked, “Are take-home active-learning exercises equal to in-class active-learning exercises in promoting student learning in undergraduate introductory biology classes?” We hypothesized that in-class and take-home active learning exercises support higher learning gains than traditional lecture and that in-class active-learning exercises promote higher gains than take-home active learning exercises.

Three sections of General Biology I were taught at Frostburg State University in Fall 2012. Sections 1 and 2 were taught by the same faculty member, using a cross-over design. Four chapters were targeted as active-learning chapters. In each case, two chapters were paired, with the first chapter as a “warm-up” to active learning and the second chapter a more involved topic. The first set focused on metabolism and cellular respiration, while the second set focused on cell division and Mendelian genetics. When Section 1 participated in in-class active-learning exercises, Section 2 was given the same exercises as take-home homework and vice versa. Section 3 was taught by a different instructor as a more traditional lecture. All sections were given a pre-/posttest addressing major concepts for the semester.

Preliminary data indicate no significant difference in pre-/posttest gains between students who participated in in-class active learning and those given the same exercises as homework and significant gains in pre-/posttest scores in students who participated in either type of active learning of the cell division and Mendelian genetics chapters compared to students in the traditional lecture section (2-tailed t-test with unequal variance; p < 0.1). These data support the use of take-home active-learning exercises to improve student learning gains in introductory biology.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Student learning, Teaching approaches

20-B
Comparisons of Two Presentation Formats: Traditional PowerPoint and Pecha Kucha
M.-K. Liao. Furman University, Greenville, SC.

Oral presentation assignments help students develop independent learning skills. In the process of preparing a presentation, students search and evaluate information (evidence-based engagement), decide whether to include it (content relevancy), organize information in a logical manner (audience engagement), adhere to the instructions (logistics) and attempt to appear credible (credibility). The final product is often a traditional 10–15 minute PowerPoint presentation. An alternative presentation format is Pecha Kucha—20 slides shown for 20 seconds each. Instructors who have adopted Pecha Kucha have claimed that it is pedagogically superior to traditional presentations. However, while studies have shown that Pecha Kucha improves student presentation and communication competence, its impacts on learning have never been examined. Involving students in three classes, this study was designed to test the hypothesis that Pecha Kucha offers students a better learning experience. Each group of students was responsible for one independent project, and each project had two phases of research and presentation. Phase I presentation took place at midterm and phase II presentation at the end. In one course, phase
I presentation was in the Pecha Kucha format and phase II was in a traditional format. In another two courses, phase I was in traditional while phase II was in Pecha Kucha. Five decision-making processes in presentation preparation were assessed through 30 questions: evidence-based engagement, content relevancy, audience engagement, logistics, and credibility. Also assessed were the students’ confidence levels in presenting their projects to experts and to novices. Results (student’s paired t-test) indicated that there were no statistically significant differences between the two formats in all five areas. Students in both groups became significantly more confident in presenting to experts at the end of the term (p = 0.02, p = 0.05), regardless of the format. Although Pecha Kucha did not seem to engage students differently, students reported that they preferred listening to Pecha Kucha than to traditional PowerPoint presentations.

**ASM Curriculum Guideline Concept(s):** Systems, Impact of microorganisms

**Pedagogical Category(ies):** Hands-on projects, Teaching approaches

**21-A**

**An Alternative Approach to “Identification of Unknowns”: Designing a Protocol to Verify the Identities of Nitrogen-Fixing Bacteria**

B.M. Martinez-Vaz. Hamline University, Saint Paul, MN.

Most Microbiology courses include a laboratory activity on the identification of unknown microbes. This exercise consists of providing students with microbial cultures and running a series of staining procedures and biochemical assays to identify the organisms. However, this approach lacks molecular techniques, such as sequencing of genes encoding 16SRNA, which is currently the method of choice for identification of unknown bacteria. A laboratory activity was developed to teach students how to identify microorganisms using 16SRNA PCR and validate their identity using classic biochemical techniques and staining procedures. We hypothesized that designing an experimental protocol to confirm the identity of a bacterium will improve students’ knowledge of microbial identification techniques and the organism’s morphological, cultural, and physiological characteristics. Nitrogen-fixing bacteria were isolated from the root nodules of Medicago truncatula and prepared for 16SRNA PCR analysis. Once DNA sequencing revealed the identity of the organisms, the students searched the available literature to learn about the properties of rhizobia and designed an experimental protocol to verify their identity. This laboratory activity was field tested over two semesters with a total of thirty Biology students (juniors and seniors) enrolled in the General Microbiology course at Hamline University. An assessment was conducted by analyzing pre- and posttests scores and by grading student worksheets and laboratory presentations. The assessment showed that average student scores increased from 66% to 80% after the completion of this laboratory activity. The highest normalized learning gains (G) were obtained for learning objectives addressing appropriate selection of microbial identification methods (G = 0.50) and recognizing the physiological and biochemical properties of nitrogen fixing bacteria (G = 0.62). The assessment data suggested that this laboratory activity improves students’ learning and is a suitable alternative to traditional “identification of unknowns” projects.

**ASM Curriculum Guideline Concept(s):** Structure and function

**Pedagogical Category(ies):** Hands-on projects, Teaching approaches

**22-B**

**Stepping Back to Go Forward: Using Progressive Clinical Cases to Enhance Understanding of Neuroendocrine Concepts**

L.J. Mauro and A. Contreras. University of Minnesota, St. Paul, MN.

The hypothalamic-pituitary-target organ axis is a critical concept for understanding neuroendocrine regulation of biological processes. Yet, it is one that students struggle to understand and for which little information on teaching approaches and learning outcomes is known. The goal of this study was to examine the effectiveness of progressive clinical cases in students’ understanding of the hypothalamic-pituitary-gonadal (HPG) axis. The hypotheses were that, using this approach would result in: 1) enhanced understanding of the function and regulation of the HPG as students progress through the cases (assessed by pre-/posttests); 2) a positive perception of this learning method and its benefits (assessed by surveys); and 3) retention of this information through the semester. Simple ‘Qwik cases’ were introduced that presented the diagnosis and required the students to work backwards to diagnostic tests and symptoms. More complex ‘full cases’ followed, where students had to apply their knowledge, working forward to a diagnosis. A pretest was given on the first day of class and posttests after Qwik cases (A), full cases (B) and as a question set included on the final exam (C). Anonymous online surveys coincided with posttests A and B. Sampling took place during the Fall semesters of 2011 and 2012. Students performed better on all posttests as compared to the pretest (n = 28–36; p = 0.0004). This gain was seen for both the function (p = 0.0003) and the regulation (p < 0.0001) subconcepts. Students agreed that the Qwik cases (81.6 ± 7%) and the full cases (79.2 ± 2%) improved their understanding and interest in the material and that the progression from Qwik to full cases was helpful (81.1 ± 6%). Scores on posttest C were greater than the pretest (p < 0.001) but not when compared to the other posttests, suggesting that the students did retain an understanding through the semester, but that they did not show an improvement in their scores as they progressed from posttests A to C. In conclusion, the use of progressive
clinical cases appears to enhance student understanding of, and interest in, this important biological concept and may help with retention of this material.

**ASM Curriculum Guideline Concept(s):** Evolution, Pathways  
**Pedagogical Category(ies):** Course design

**24-B**  
**Using the Research-Based High School “Discover the Microbes Within: The Wolbachia Project!” in the College Classroom**  
G.T. May and J.P. Odden. Metropolitan State University of Denver, Denver, CO.

Recent studies emphasize the value of incorporating undergraduate research into classrooms. From 2011–2012, five modules from “Discover the Microbes Within: The Wolbachia Project” (S.R. Bordenstein et al., 2010 American Biology Teacher 72, 478) were incorporated into two upper division elective courses. Originally designed for hands-on research in high schools, we hypothesized that the molecular activities would also benefit college students by 1) increasing their interest in research and 2) improving self-assessed laboratory skills. During this lab unit, students collected insects, extracted DNA, set up polymerase chain reactions (PCR), performed gel electrophoresis, and used BLAST analysis to determine if their insects were Wolbachia infected.

We administered a pre- and postsurvey tool designed for the high school “Wolbachia Project.” This survey assessed student responses in seven areas, including laboratory skills and intention to study science. Despite open-ended written comments in which students indicated that they were already very interested to study science, analysis of student responses to the intention to study science questions revealed a decreased interest following the laboratory exercise; the mean score of student responses decreased by 8% (n = 44) on a 5-point scale from 4.18 (presurvey) to 3.87 (postsurvey), where response 3 corresponded to “mostly true.” It is possible some students were turned off by research-oriented activities; a wide variety of biology majors and minors are enrolled in these courses. For the laboratory skills questions, the mean value of student responses increased by 20% (n = 44) on a 3-point scale from 1.92 (presurvey) to 2.31 (postsurvey), where response 1 corresponded to “new to me,” response 2 corresponded to “need to practice,” and response 3 corresponded to “routine for me.” Data from this study led us to conclude that the Wolbachia Project decreased student intent to study science. We also conclude that student-assessed laboratory skills increased through these research-based modules.

**ASM Curriculum Guideline Concept(s):** Impact of microorganisms  
**Pedagogical Category(ies):** Hands-on projects

**25-A**  
**Undergraduate and Graduate Students’ Perception of Virtual Education**  
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2Universidad Catolica de Asuncion, Asuncion, Paraguay.
Internet access in Paraguay is still not as widespread as in other countries. Virtual education was implemented at a Paraguayan university, at the undergraduate level, about three years ago. Its implementation at the graduate level started more recently. This work evaluates the perception of undergraduate students (UGS) and graduate students (GS) of the advantages and disadvantages of virtual education in microbiology. The hypothesis is that UGS have greater ease and experience with virtual education. Both groups were asked to complete a web survey. The survey included eight questions with closed answers and two about personal characteristics. It was eventually completed by 44 GS and 60 UGS. This report summarizes only the questions that had the most answers from each group. About the training needs of teachers and students in relation to the virtual approach to education, 36.4% of GS responded that teachers must know how to use the time available to answer questions and strive to be technologically up to date. Time management by students was the most important issue for 46.7% of UGS. The major advantage to students of using virtual education, according to both groups (40.9% of GS, 45.0% of UGS), was that it allows studying to be adapted to the student’s personal schedule. The drawbacks were the need for access to certain technological tools (36.4% of GS), and the delayed or slow feedback and error correction (38.3% of UGS). The major advantage of virtual platforms for 61.0% of GS was the ease of access to information, and to 48.3% of UGS was that it encourages debates and discussions. The main disadvantages were indicated to be the need to have motivated and involved students (44.2% of GS), and the technological division between teachers and students (50.0% of UGS). It was concluded that GS are more concerned with access to, and use of, this tool, and that UGS are not concerned about the use of, and problems with, the internet. UGS are more concerned with improving teaching strategies and minimizing the technological division between teachers and students for a better use of virtual education.

**ASM Curriculum Guideline Concept(s):** Impact of microorganisms

**Pedagogical Category(ies):** Course design, Teaching tools

**26-B**

**Use of an Immunology-Based CREATE Module Improves Student Understanding of the Interconnectedness of the Immune System**

**H.R. Pelzel.** University of Wisconsin - Whitewater, Whitewater, WI.

Immunology is a complex topic for students to understand, in part due to the sheer volume of terms but also the intricacy of the functional relationships of the many parts. My microbiology students generate concept maps at the end of an immunology unit to help them visualize the ties among parts of the immune system. I have found that the maps they created looked like flow charts with very little webbing, indicating a lack of comprehension of the interconnectedness of the parts of the immune system. To improve student understanding of the immune system, I chose to integrate an immunology-based CREATE module to specifically address the interplay among the parts of the immune system and between the immune system and pathogens in disease processes. My hypothesis is that working through the three primary research articles that compose the module will strengthen students’ understanding of how the pieces of the immune system work in concert to battle infections. To begin to test this hypothesis, I made comparisons between concept maps from students in my CREATE class and students from 2 previous semesters who did not use the module.

All classes were given identical seed concepts and instructions on creating a concept map. The non-CREATE student groups (n = 9) used 15.7 ± 0.4 (ave ± SE) concepts with 16.1 ± 0.8 links per map, while the CREATE student groups (n = 4) utilized 20.5 ± 3.0 concepts with 25.8 ± 2.5 links per map (p = 0.015 (concepts) and p = 0.0003 (links)). The largest difference between the two groups was found in the number of labeled links that were present on the maps (1.2 ± 0.6 for non-CREATE vs. 21.8 ± 3.0 for the CREATE class, p = 5.7 × 10^{-7}). While this was a small pilot study that needs to be further examined, the results suggest that the use of an immunology-based CREATE module had a strong impact on the students’ understanding of the basic concepts of the immune system and the interplay between its various parts, as evidenced by the improved intricacies of their concept maps. Additional repetitions and assessments are still needed and will be examined to continue to explore the benefits of the immunology-based CREATE module to the general microbiology classroom.

**ASM Curriculum Guideline Concept(s):** Systems, Advancing STEM education and research

**Pedagogical Category(ies):** Teaching tools

**27-A**

**Implementing Vision and Change: Bringing Undergraduate Research to a Non-Research Biology Program through BioSOLVE Courses and Application-Based Service Learning (ABSL) Pedagogy**

**G.E. Rowe.** La Roche College, Pittsburgh, PA.

La Roche College is a small college with resources and faculty dedicated to classroom teaching but little option for student research. To improve biology student research within our limits, I created BioSOLVE I & II as a new model of ABSL. ABSL combines novel research and service focused on a community issue, all within a structured class (N. Trun, AAAS Vision & Change conference, 2009). BioSOLVE I students learn about scientific
research, a community issue, and biology theory and lab skills to address the issue. BioSOLVE II students focus on lab research. Both courses require community service and engage students in all aspects of novel research. We collaborate on the Feral Cat Project (Trun, AAAS, 2009) as our community issue. To test the hypothesis that BioSOLVE improved the quantity and quality of biology student research, I assessed data from 4.5 years of BioSOLVE. A course evaluation showed all students liked the research and service, felt the combination was an effective way to learn, and would recommend the course to others. Analytical, communication, and lab skills were assessed by graded lab performance, lab notebooks, scientific writing and oral presentations. All students earned high grades, similar to their other science courses. Course evaluation comments showed an understanding of novel research, including rewards and challenges. Twenty-two students were involved in research in 4.5 years of BioSOLVE, compared to 8 students over the previous 12 years combined. Ten BioSOLVE students worked on the same project for 2–4 semesters, compared to only 1 prior student working beyond one semester. Six of the 10 BioSOLVE II students did additional research credits. Three of those 6 did Honors research projects; 2 won a campus-wide competition for best Honors presentation. In the previous 12 years, no biology student did an Honors project. BioSOLVE alumni had excellent success obtaining research internships, graduate school admission, and graduate scholarships. Thus, BioSOLVE increased student interest and involvement in biology laboratory research, created an ongoing cohort of student researchers, and may serve as a model for other small, non-research colleges.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Teaching approaches

### 28-B

**Mixed-Methods Assessment Approach Reveals Learning Gains for Research Immersion Lab in Virology**  
**E.R. Sanders, J. Moberg-Parker, C. Shapiro, C. Ayon, S. Toma, and M. Levis-Fitzgerald. University of California, Los Angeles, Los Angeles, CA.**

Implementation of an interdepartmental, research-based laboratory curriculum involving over 250 UCLA life sciences majors per year is underway. Students experience the process of discovery as participants in team-based research projects spanning two quarters. We hypothesized that students would demonstrate learning gains in higher-order cognitive skills (HOCS) associated with the research process. To test this hypothesis, we are utilizing a mixed-methods assessment approach, analyzing data from a rubric-guided evaluation of course assignments and self-report instruments. Bloom’s Taxonomy was used to classify performance indicators on assignments and surveys, and scores for items categorized as HOCS were compared at two time points. This study focuses on a virology lab in which students use the host Propionibacterium acnes to cultivate novel phages from their skin. Of 12 students completing the P. acnes project in Fall 2012, 10 (83%) participated in entry/exit surveys in which they estimated their skill level (3-pt scale) at the start and end of the program. Mean differences (md) were calculated, with students reporting significant learning gains (p ≤ 0.05) in several HOCS categories, including writing reports (md = 0.9), devising hypotheses (md = 0.9), analyzing scientific data (md = 0.8), and solving problems collaboratively (md = 0.7). Paired-samples t-tests also reveal significant changes (p ≤ 0.05) in levels of experience (5-pt scale) with bioinformatics tools (md = 2.0). 71% of students who completed the surveys expressed an increased level of interest in biology after completing the course, with about two-thirds of the students citing real-world relevance and practical applications of the project as attributing factors. Thematic analysis of reflection questions in a course assignment indicate having a personal connection to the project helped promote student engagement. Trends in learning gains, observed with outcomes data from performance evaluation of research presentation slides by a content evaluator, will provide direct evidence students are achieving specified learning outcomes as suggested by self-report data.

**ASM Curriculum Guideline Concept(s):** Impact of microorganisms, Advancing STEM education and research  
**Pedagogical Category(ies):** Student learning

### 29-A

**Team-Based Learning Enhances Course Content Retention in a Hybrid Classroom**  
**H.M. Seitz. Johnson County Community College, Overland Park, KS.**

In hybrid courses with reduced class time there is often less time for instructors to reinforce concepts and thus retention of course content is a problem. My hypothesis is that team-based learning will enhance student retention of course content. Team based learning has been shown to increase student performance and increase students’ retention of course content. This study examines whether the same content-retention gains can be seen in a hybrid classroom. To determine if retention was improved four hybrid sections of microbiology were examined. Two sections used team-based learning and two sections had a traditional classroom setting. The team-based learning consisted of putting the students into teams for the entire semester and assigning problem solving tasks that were completed as a team. The traditional classroom completed the same tasks but did not have set teams and completed the activities as a class discussion. Course content retention was measured using...
posttests looking at questions from the first unit of study compared with the last unit of study. In addition, students were asked to look at their syllabus and reflect on the material they learned in each unit. These reflections were scored by looking at whether the students discussed key learning concepts from the first unit compared with the last unit of the course. The results of this study indicated that students in team-based learning scored 83% on posttest questions covering the first unit of study compared with traditional classroom students who scored 73% on first-unit questions. The scores on the last unit of study were 80% and 81% respectively. Semester reflections showed that 97% of team-based learning students correctly discussed a learning objective from the first unit on their reflection while only 50% of traditional classroom students correctly discussed a learning objective from the first unit. Data from the first unit were again compared with the last unit of study and no difference was seen. In conclusion, this study indicates that team-based learning can be used as a teaching method to increase student retention of information in hybrid courses with reduced class time.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Teaching approaches

### 30-B  
**Course-Based Research is Effective in Engaging Students in ‘Real’ Science: Soil Bacterial Diversity Research in an Undergraduate Microbiology Course**  
**A. Shanmuganathan.** Washington & Jefferson College, Washington, PA.

To provide research experience early and provide it to those who do not undertake summer research, undergraduate course-based research is ideal. But, is course-based research effective in engaging students in ‘real’ science? To investigate this, a research-based lab curriculum centered on soil bacterial diversity was implemented in an undergraduate microbiology course at W & J College from 2010–2012, and assessed. It was hypothesized that this course-based research would effectively engage students in the scientific process in a manner comparable to non-course-based research. Students designed a project to test the effect of an abiotic factor on soil bacterial diversity. They cultured soil bacteria and obtained bacterial 16S rDNA. Using RFLP and bioinformatics (sequence) analysis of 16S rDNA, soil bacterial diversity was characterized. Student outcomes were assessed using CURE (Classroom Undergraduate Research Experience) surveys. For the 50 students surveyed, course elements relevant to design of study, collecting, analyzing, and presenting data showed substantial increases in the post-course survey compared to the pre-course survey (pretest = 3.37 ± 0.09; posttest = 3.84 ± 0.1). Learning gains made from this course-based research (n(exp) = 50) were compared with learning gains in other course-based research and summer research (n(other) = 4465). In categories such as “understanding the research process” (exp = 3.69 ± 0.14; other = 3.52 ± 0.02) and “ability to analyze data and other information” (exp = 3.66 ± 0.25; other = 3.76 ± 0.04), the two groups were similar. In categories such as “learning lab techniques” (exp = 4.08 ± 0.26; other = 3.77 ± 0.11), “ability to read and understand scientific literature” (exp = 3.68 ± 0.09; other = 3.39 ± 0.09) and “skill in science writing” (exp = 3.94 ± 0.27; other = 3.42 ± 0.09), students undertaking this course-based soil bacterial diversity research (exp) showed higher learning gains than all other students (other). In conclusion, this course-based research effectively teaches elements of the scientific process and is at least as effective as undertaking other course-based research or summer research.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Hands-on projects

### 31-A  
**Assessment of a Novel Group-Centered Testing Schema in an Upper-Level Undergraduate Molecular Biotechnology Course**  
**M.C. Srougi1, H.B. Miller2, D.S. Witherow2, and S. Carson1.**  
1North Carolina State University, Raleigh, NC, 2High Point University, High Point, NC, 3University of Tampa, Tampa, FL.

Providing students with assignments that focus on critical thinking is an important part of their scientific and intellectual development. However, as class sizes increase, so does the grading burden, prohibiting many faculty from incorporating critical thinking assignments into the classroom. In an effort to continue to provide our students with meaningful critical thinking exercises, we implemented a novel group-centered, problem-based testing scheme. We hypothesized that having students perform critical thinking problem sets as group work, compared to performing the sets as individual work, would improve final cumulative exam scores and be positively received by students. During two semesters of our recombinant DNA course, students had the same lecture material and similar assessments. In the Fall semester (n = 68), student learning was assessed by two collaborative take-home exams, followed immediately by individual, closed-book, in-class exams on the same content, as well as a final cumulative exam. Student teams on the take-home exams were instructor-assigned, and each team turned in one collaborative exam. In the Spring semester (n = 56), the control group of students were required to turn in their own individual take-home exams, followed by the in-class exams and final cumulative exam. For the majority of students, learning outcomes were met, regardless of whether they worked in teams. However, students working in instructor-assigned teams significantly outperformed the control cohort on the final cumulative exam, 81.37% vs. 76.67%, respectively, by an
average of 4.7% (p ≤ 0.01). In addition, 87% of students working in teams strongly agreed/agreed that collaborative learning helped them grasp the course material and grading was reduced for instructors. These data suggest that group-centered, problem-based learning is a useful model for achievement of student learning outcomes in courses where it would be infeasible to provide feedback on individual critical thinking assignments due to grading volume.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Course design, Student learning

### 32-B  
**Students’ Behaviors and Attitudes in a Problem-Solving Exercise Leading to an Oral Mini-Test**  
W.J. Staddon. Eastern Kentucky University, Richmond, KY.

Students were given problems in my microbiology class that required them to apply and synthesize various aspects of the course content including information flow, gene regulation, pathways, and host defenses. Students worked on these problems in groups and were evaluated using individual, oral mini-tests. This preliminary investigation attempted to characterize classroom dynamics and student behavior during the exercise. It was hypothesized that student understanding and engagement would be related. Further, grit may predict student behavior. Surveys were administered addressing factors that might be relevant to the exercise, including student interactions and confidence. Included was a grit survey (Duckworth and Quinn, 2009) that assessed students’ tenacity. Students responded using a Likert scale and relationships between variables were determined using Pearson’s correlation coefficient. Students who understood the problems on their own were likely able to develop their own answers (p < 0.001). Students requiring help from others were less able to develop answers on their own (p < 0.001) and did not benefit from thinking about the problems on their own (p < 0.001). The capacities of individuals to understand the problems and develop answers were not related to active engagement in class discussions. Interestingly, the ability to understand the problem on their own and develop their own answers were not related to the students’ desire to have more of their course grade depend on this type of exercise. Grit was unrelated to the students’ ability to understand the problem and develop answers on their own. However, this trait was positively associated with active engagement (p = 0.06) and increasing engagement (p < 0.01) during class discussions. Grit and willingness to have grades depend on this type of exercise were positively, but not significantly, correlated (p = 0.11). Confidence in their answer did not appear to alleviate students’ nervousness during the oral mini-test. These results are based on a single exercise in Fall 2012. Data collected in the spring of 2013 for each of three rounds of problems will also be presented.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Course design, Student learning

### 33-A  
**Metacognitive Regulation Training to Improve Student Performance in Introductory Biology**  
J.D. Stanton and T.C. Byington. Washington State University, Pullman, WA.

The percentage of students who do not pass introductory biology is alarmingly high, reaching up to 40% in universities across the country. While recent studies have focused on helping students practice higher-order thinking skills, the effect of metacognitive training on student performance in introductory biology has not been well studied. Metacognition can be divided into metacognitive knowledge (what we know about our own thinking) and metacognitive regulation (how we control our thinking to facilitate our learning). We hypothesized that providing students with the opportunity to learn metacognitive regulation skills would increase their metacognition and result in increased exam performance. In Fall 2012, short metacognition units were added to a large introductory biology lecture course, and students were guided through an exam reflection assignment designed to help them evaluate their approach to preparing for the first exam and create a plan for the second exam. To measure pre- and post-course metacognition, the Metacognitive Assessment Inventory (MAI) was used, and student performance was measured by comparing exam grades before and after the training. Preliminary analysis revealed that students’ overall pre- and post-course MAI scores did not change significantly, although scores on MAI questions specifically directed at evaluation skills increased. Additionally, an increase in the class average on the second exam (73.05%) was observed. We conclude that completion of the exam reflection assignment correlates with an increase in exam performance, but that the initial metacognitive regulation training was too brief, and needs to be extended. Complete analysis of this project will include a comparison of data from Fall 2012 and Spring 2013, and qualitative assessment of written responses to the exam reflection assignment. We predict that high-quality answers on the assignment will correlate with increased MAI and exam scores. This study is expected to contribute to our understanding of the effect of metacognitive regulation on student performance.

**ASM Curriculum Guideline Concept(s):** Advancing STEM education and research  
**Pedagogical Category(ies):** Course design, Student learning
Misconceptions about key learning concepts often create barriers to the ability of students to acquire new knowledge. If instructors are unaware of these misconceptions, they will persist, but awareness of them enables the development of appropriate classroom intervention strategies. A validated two-tiered concept inventory for microbiology (HPI Concept Inventory) was used to assess student understanding of key learning concepts through pre- and postsurvey given to students in several microbiology courses throughout the curriculum (from lower- to higher-level courses). It was hypothesized that analysis of student explanations to their answers on the presurvey taken at the beginning of their first class in General Microbiology would reveal key misconceptions they harbor before receiving formal instruction on the subject. Student responses to five questions from the HPI-CI related to the subject of antibiotic resistance were selected for initial qualitative analysis. Presurvey data were collected from the use of the HPI-CI in six distinct offerings of General Microbiology. Teams of faculty (from instructors to research-active faculty) at two peer institutions coded student explanations (~500 individual responses per question) associated with student HPI-CI multiple choice-response selections. Some of the most common misconceptions related to the function/targets of antibiotics, the structural difference between Gram-positive and Gram-negative bacteria, the role of genetic change in resistance, and vernacular misuse. Thus it can be concluded that students do harbor significant misconceptions prior to completing General Microbiology. The codebook of misconceptions generated from the first phase of assessment data analysis is now being used to quantitatively categorize these misconceptions. A subsequent analysis of student responses in the postsurvey for General Microbiology will reveal what concepts remain after instruction and what new ones have emerged due to instruction. As the process is repeated in courses through the curriculum, evidence-based reform in individual classes and the curriculum will be implemented.

ASM Curriculum Guideline Concept(s): Structure and function
Pedagogical Category(ies): Student learning

35-A
Refining Undergraduates’ Focus on Microscopy in the General Microbiology Lab
S.C. Wagner and J. Taylor. Stephen F. Austin State University, Nacogdoches, TX.

Undergraduates in general microbiology courses are typically trained to use compound brightfield microscopes and rarely exposed to other instruments, such as darkfield, phase contrast, fluorescence, and electron microscopes. We hypothesized that students would improve their understanding and appreciation of these microscopes if they were able to use them directly. New lab exercises were developed where students began in traditional labs that cover the components, care, and maintenance of brightfield microscopes and viewing specimens such as plankton, yeasts, and bacteria. During subsequent lab periods students engaged in hands-on activities in our electron microscopy center where they studied preparing specimens for viewing and operation of both scanning and transmission electron microscopes. The students then worked in teams to view and interpret electron micrographs of specimens generated by the instruments. A pre- and posttest measured the students’ comprehension of basic concepts, including an understanding of resolving power, how images are formed by compound light and electron microscopes, how specimens are prepared for light and electron microscopy, and the applications of different forms of microscopy. The test included both objective and subjective questions and was administered to 17 and 20 students during the Spring and Fall 2012 semesters, respectively. The mean score on the pretest was 44% and 40% for the Spring and Fall semesters, respectively; this value improved to 70% and 63% on the posttest. All students over the two semesters improved in their level of knowledge as a result of the activity; the range of improvement was 9–36%, with a mean value of 24%. The results revealed that this approach helped the students to appreciate the array of microscopic tools available and to understand the applications of each instrument. Students were effectively engaged through active learning, improved in their content knowledge, and were directly exposed to research techniques. In the future we plan to expand the number of laboratory exercises where we employ this type of approach.

ASM Curriculum Guideline Concept(s): Structure and function, Advancing STEM education and research
Pedagogical Category(ies): Hands-on projects

36-B
Microbiology Outreach in an AP Biology Classroom Using Undergraduates as Facilitators Increases High School Student Knowledge and Appreciation for Microbiology Topics
A.H. Williams, C.R. Wood, D.K. Palamittam, S.E. Mathis, N.M. Jawahir, and A.R. Grotton. University of Tampa, Tampa, FL.

This outreach project tested the hypothesis that the delivery of material in a case study and hands-on experimental approach to high school students by an undergraduate
student teaching team will result in the students being actively engaged in science topics, leading to an increased appreciation of and learning of science topics, specifically microbiology-centered topics. A team involving an undergraduate institution (students and faculty), a high school classroom (AP biology students and teacher), and STEM administrators administered a case study teaching module in the Florida public school system. The undergraduate students created the case study teaching module, prepared the materials needed to deliver the project, and then delivered the teaching and assessment module to students in an AP Biology high school class. To assess increase in knowledge and appreciation for the sciences, specifically microbiology, pre- and posttests were given to the students along with a numbered survey including open-ended questions. The scores on the posttest (mean = 60.7%) were significantly higher than the scores for the pretest (mean = 38%) with a 23% increase in the mean (p < 0.0001, p-value = 3.236e-06), indicating an increase in understanding of microbiology material. This increase in knowledge could be due in part to the delivery of material as a case study and hands-on activity as the material on the exam had previously been covered in the high school course. For the survey statements, “Overall, I feel more confident about the material covered in class and know more about microbiology,” 15 of the 16 students answered Strongly Agree (5). For the question, “I believe this project was useful and beneficial,” all 16 students answered Strongly Agree (5). One student commented, “This was incredibly helpful and helped me to understand microbiology immensely.” In conclusion, the high school students gained understanding and appreciation of microbiology topics when material was delivered by biology undergraduate students in a hands-on, case study manner. This is evident through their significant improvement on knowledge exam questions and a hands-on, case study manner. This is evident through their

**ASG Curriculum Guideline Concept(s):** Impact of microorganisms, Advancing STEM education and research

**Pedagogical Category(ies):** Hands-on projects

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