Can a Flipped-Classroom Approach in Combination with Inquiry-Based Learning Foster Content Acquisition and Hypothesis Testing in Introductory Biochemistry?
I.H. Barrette-Ng.
University of Calgary, Calgary, Alberta, Canada.

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

Implementation of an Introductory Biology Large Course Redesign Facilitated by Undergraduate Learning Assistants
T.C. Bates and J.M. Warner.
The University of North Carolina at Charlotte, Charlotte, NC.

ASM Curriculum Guideline Concept(s): Advancing STEM education and research
Pedagogical Category(ies): Course design
3-A
STEMM: Sequencing Technology Education using Microbial Metagenomes
E.A. Dinsdale and R.A. Edwards.
San Diego State University, San Diego, CA.

ASM Curriculum Guideline Concept(s): Impact of microorganisms, Advancing STEM education and research
Pedagogical Category(ies): Hands-on projects, Student learning
American Academy of Microbiology Topic: The Human Microbiome

4-B
Biology Service Learning Increased the Success of Freshman Biology Majors at Academic Risk in the First Semester Biology Course
D.F. Fox.
Spring Hill College, Mobile, AL.

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

5-A
Cheese Microbiology and Biochemistry: A Laboratory Activity
M.A. Furlong and R.E. McFarlane.
Clayton State University, Morrow, GA.

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

6-B
Comparable Benefits of an Inquiry-Driven Introductory Biology Course and a Summer Research Experience
L.A. Gregg-Jolly and J.C. Sandquist.
Grinnell College, Grinnell, IA.

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

7-A
Variation in Student Response to an Authentic Research Experience
H.J. Henter, M.M. Butler, and S.F. Mel.
University of California San Diego, La Jolla, CA.

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

8-B
Student Reaction to Nontraditional Teaching in a Test of CREATE on Seven Campuses
S.G. Hoskins1 and L.M. Stevens2.
1City College of the City University of New York, New York, NY; 2University of Texas, Austin, Austin, TX.

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

9-A
A Large Course Redesign of a General Microbiology Lecture Course Incorporating a Student-Centered Active Learning Environment with Upside-Down Pedagogies (SCALE-UP)
A.M. Lee, M.G. Keen, T.I. Petty, M. Miller-Kittrell, and J.M. Bradshaw.
North Carolina State University, Raleigh, NC.

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

10-B
Building Skills for Complex Problem Solving through Explicit Instruction
M. Leonard.
Mount Mary University, Milwaukee, WI.

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

11-A
Effects of a Classroom-Based Authentic Research Experience on Learning Genetics Concepts
C.A. MacKinnon and J. Cuellar Fuentes.
University of the Incarnate Word, San Antonio, TX.

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

12-B
Outcome-Based Method to Assess Student Learning over Different Time-Scales
J. Moberg-Parker, D. Pires, C. Shapiro, M. Levis-Fitzgerald, and E.R. Sanders.
University of California Los Angeles, Los Angeles, CA.

ASM Curriculum Guideline Concept(s): Evolution, Advancing STEM education and research
Pedagogical Category(ies): Student learning
The Emerging Microbe Project: Synthesis of Pathogen Identification and a Clinical Case Study in a Doctor of Pharmacy Infectious Disease Course
L.A. O’Donnell, M.W. Perry, and D. Doup.
Duquesne University, Pittsburgh, PA.

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

Immunological Tools: Engaging Students in the Use and Analysis of Flow Cytometry and Enzyme-Linked Immunosorbent Assay (ELISA)
L.E. Ott and S. Carson.
North Carolina State University, Raleigh, NC.

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

Using Community Partners to Effectively Engage Students in Microbiology Research
K.A. Page.
Southern Oregon University, Ashland, OR.

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

Do Student-Generated Visual Models Promote Learning because They Are Active, Visual, or Both?
K.J. Quillin.
Salisbury University, Salisbury, MD.

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

Teaching Scientific Writing and Reasoning using Peer Assessment
I.K. Reed, C.A. Millard, D. Carillo, and S.J. Pearlman.
University of Saint Joseph, West Hartford, CT.

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

Increases in Core Concept Knowledge within a Comparative Genomics Multi-Section Introductory Laboratory Class
H.N. Rowedder, C.M. O’Connor, and D.M. Warner.
Boston College, Chestnut Hill, MA.

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

This Flippin’ Class: Attitudes About Learning in a Flipped Microbiology Classroom
H.M. Seitz.
Johnson County Community College, Overland Park, KS.

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

Bacteria in the Dirt: An Inquiry-Based Lab Curriculum in the First Biology Core Course
A. Shanmuganathan.
Washington & Jefferson College, Washington, PA.

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

Selective Flipping: A Problem Solving-Based Approach to Teaching DNA Replication
A. Shanmuganathan.
Washington & Jefferson College, Washington, PA.

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

Mining Concept Inventory Data For Student Alternate Conceptions
A.C. Smith, S. Balcom, J. Buchner, V. Briken, J. Destefano, B. Fredericksen, S. Hucheson, N. El-Sayed, K. Frauwirth, V. Lee, G. Marbach-Ad, K. McIver, D. Mosser, P. Shields, W. Song, D.C. Stein, R. Stewart, K. Thompson, S. Yarwood, and B. Quimby.
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**ASM Curriculum Guideline Concept(s):** Evolution, Advancing STEM education and research
**Pedagogical Category(ies):** Student learning
Hypothesis testing is central not only to the scientific method but also to understanding the nature of scientific knowledge. Although it is widely appreciated that students should develop hypothesis-testing skills earlier in their undergraduate careers, there are many challenges preventing students from engaging in scientific inquiry in large-enrollment classes (500–1000 students). The hypothesis of this study is that by combining collaborative in-class activities with problem-based computer simulation software, an effective environment can be created to foster both content acquisition and the development of scientific inquiry skills such as hypothesis testing. Four inquiry-based modules were introduced in winter 2012 to cohort A, a class of 500 students in introductory biochemistry. Each module consisted of a podcast reviewing essential concepts, an in-class peer-learning activity based on formative assessment principles, and an interactive student-centered JAVA computer simulation in which each student is provided with the opportunity to design a virtual experiment, formulate a hypothesis, and record and interpret the results of the simulation. To assess the impact of these modules on learning, three approaches were developed. First, the ability of students in cohort A to solve problems that required hypothesis testing was compared with that of students who completed the course prior to the introduction of the four modules (cohort B). Whereas 90% of students in cohort A correctly solved these problems, only 50% of students in cohort B were successful ($p<0.001$). Second, a Biochemistry Concept Inventory was administered to assess content acquisition in cohorts A and B. Preliminary data indicate a significant difference between the two cohorts. Third, a subjective self-assessment survey was administered to cohort A to assess student perceptions about the modules, and feedback has been generally positive. Altogether, these data suggest that a combination of peer-learning in-class activities and problem-based computer simulation software fosters both the acquisition of content and the development of scientific inquiry skills.
voicing questions and concerns to a peer LA. Overall, we were able to redesign our course so that it actively engages students, encourages collaborative learning, and provides frequent formative assessment and feedback to students. Prior to implementation of the redesigned course, the proportion of students (N=1186) earning a grade of D or F in the course was 25.92% with an average grade of 2.28 (on a 4.0 point scale). For the three semesters following the implementation of the redesigned course, the proportion of students (N=995) earning a grade of D or F in the course was reduced to 19.82% with an average course grade of 2.51. Additionally, feedback related to student satisfaction in the course was very positive. We expect to see a further reduction of D and F grades as we refine our redesign and continue working with LAs.

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

**Pedagogical Category(ies):** Course design

### STEMM: Sequencing Technology Education using Microbial Metagenomes

**E.A. Dinsdale** and R.A. Edwards. San Diego State University, San Diego, CA.

The revolution in DNA sequencing technology continues to dramatically change microbiology. The training and recruitment of the next generation of researchers who are able to use these new technologies is vital, but lagging. We developed a cross-disciplinary class that provided practical experience in using next generation sequencing instruments, covering every step from DNA extraction, through sequencing, to genome annotation. The class has been taught 3 times and the students have sequenced approximately 40 microbial genomes, 60 metagenomes, and the California Sea Lion.

The student body was culturally diverse, and included Junior and Senior undergraduates, MSc and PhD graduates. The course brought together biologists and computer science students. By having the two groups of students work side by side, the computer scientists learned biology and the biologists learned computational constraints. Both groups of students learned research techniques.

We hypothesized that students would learn about DNA sequencing and increase their ability to conduct science. Students’ perceived ability was measured in 1) the scientific process, 2) genomic sequencing and annotation, 3) biology, and 4) computer science. A 66-item pre- and post-test was conducted. The surveys used a Likert scale and reliability was tested using Cronbach’s alpha. Significance was tested using matched paired t-test. Students improved in their perceived ability to conduct science: Class 1 – 3.3 to 3.8 (t=-6.08; p≤0.001); Class 2 – 3.87 to 3.95 (t=-2.86; p=0.009); Class 3 – 3.55 to 3.96 (t=-8.30; p≤0.001). Students increased their knowledge of genomics by running the sequencer, discussing journal articles, analyzing the large amounts of data, and writing a formal report about their data, all skills required to become a successful scientist. The students’ scores (n=53) on the pre- and post- knowledge quiz almost doubled from 2.6 (+0.29) to 4.26 (+0.15). The students describe the course as a “must have” for a career in molecular biology.

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

**Pedagogical Category(ies):** Hands-on projects, Student learning

**American Academy of Microbiology Topic:** The Human Microbiome

### 4-B

**Biology Service Learning Increased the Success of Freshman Biology Majors at Academic Risk in the First Semester Biology Course**

**D.F. Fox.** Spring Hill College, Mobile, AL.

This K–12 collaboration examines the influence of biology community service on academic at-risk freshman biology majors. The first semester biology course at Spring Hill College has a history of 27% of the students not succeeding (W/D/F). Analysis of the data since 2007 showed that more than 60% of the freshman biology majors with ACT scores of 21–23 did not succeed in this course (W/D/F). Freshman students with ACT scores 24 and higher were likely to succeed in their first biology course. The population of students with ACT scores below 21 rarely earned a grade of C or better. The goal of this study was to determine if service learning in the form of teaching biology to 7th graders would increase the success rate of the academic at-risk college freshmen with ACT scores of 21 to 23. It was also hoped that academic success in the first semester biology course would increase the retention of biology majors. The community service opportunity was offered to freshman biology majors with ACT scores of 21–23 in the fall semesters of 2012 and 2013. The college students created several lab activities plus weekly fun review activities for a 7th grade biology class at an under-served middle school (98% of the students at this middle school are on the free lunch program). One hundred percent of students who completed the freshman biology course earned a C or better (n=16; 3 B, 2 C+, 8 C, 3 drop). The total success rate was 81% due to three students dropping the course after changing their major at midterm. In an anonymous survey, for the questions concerning “did preparing and teaching the 7th graders enhance your understanding,” the average of the responses was 3.9 on a 1 to 5 scale (1=not at all, 3= somewhat, 5=strongly agree). In conclusion, the service learning course was successful in increasing the success rate of freshman students in first semester biology. However, the assumption that success in the biology course would lead to continuing with a major in biology may be false. Only 44% of the students (n=16) are continuing on as biology majors.
The 56% that changed to a non-science major did so during their freshman year.

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

### 5-A

**Cheese Microbiology and Biochemistry: A Laboratory Activity**  
**M.A. Furlong** and **R.E. McFarlane.** Clayton State University, Morrow, GA.

Applied microbiology laboratory activities are outstanding additions to undergraduate microbiology courses since they encourage students to apply their knowledge of basic microbiology to an interesting topic that is relevant to their lives. Our proposed hypothesis is that an inquiry-based laboratory activity that covers the microbiology and biochemistry of cheese production will result in a high level of student engagement and will improve the students’ abilities to meet learning outcomes related to cheese production and cheese biology. During this activity, students designed experiments to answer a research question related to the effects of different types of rennet on aspects of cheese production. Six learning outcomes linked to skills and knowledge of cheese production, the microbiology/biochemistry of cheese, and the process of science were assessed using pre- and post- quizzes, laboratory reports, and surveys. On the surveys, students rated their skills and knowledge related to cheese production after completing the activity. The average score on this survey was 4.2 out of 5. The average grade (66.6%) on the pre- quiz was significantly lower than the average (77.8%) on the post- quiz (student t-test p<0.005). When questions on these quizzes were mapped to learning outcomes it appeared that most students improved their mastery of each outcome (>15% quiz score increase for each outcome). Analysis of the laboratory reports was used to determine the students’ ability to utilize the process of science. Rubric data from the lab reports indicated that 100% of the students were able to meet expectations (scoring >69%) and 80% exceeded expectations (scoring >89%). Historic data indicated that students score much lower when they produce laboratory reports for “cookbook” type activities. In conclusion, the perception surveys revealed that the students appeared highly engaged in the activity and felt that the activity effectively assisted them in meeting the learning goals related to cheese production. The assessment data indicated that the students improved their ability to meet the learning outcomes after completing the project.

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

### 6-B

**Comparable Benefits of an Inquiry-Driven Introductory Biology Course and a Summer Research Experience**  
**L.A. Gregg-Jolly** and **J.C. Sandquist.** Grinnell College, Grinnell, IA.

There is interest in using investigative learning in courses to generate the benefits of research experiences, in a way that is more broadly available and less resource intensive. In this study, we look at whether a single introductory biology course can provide students with comparable learning gains to a summer research experience. Grinnell College’s BIO150 Introduction to Biological Inquiry course introduces students to how biologists pose questions, design experiments, analyze data, and communicate. Individual sections have different topics, but all sections involve intensive student-directed investigation and are taught in a workshop format. Since the course design was modeled on research, it is expected that outcomes from such a course would be comparable to those of an undergraduate summer research experience. Learning gains reported from the CURE (Classroom Undergraduate Research Experience) survey by students from two sections of BIO150 are compared to those reported on the SURE (Survey of Undergraduate Research Experiences) by students who recently completed a summer undergraduate research experience. Mean student responses (n=39) to 16 out of the 21 learning gains listed in the CURE survey were higher than the same learning gains reported from SURE (n=2,714, national respondents during 2012), but none of the differences of the means in any category exceeded the standard deviation. On a 5-point scale, with 5 being the largest gain, the highest gains reported by the BIO150 students were in the categories of learning laboratory techniques (4.31, SD=1.05), ability to read and understand the scientific literature (4.24, SD=1.13), and skill in science writing (4.1, SD=1.14). These three categories were also the categories with the biggest difference compared to SURE data. Categories that were rated lower in BIO150 compared to research included clarification of a career path, learning ethical conduct, self-confidence, and learning to work independently. This supports the hypothesis that a single introductory biology course can provide comparable learning outcomes to a summer research experience.

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

### 7-A

**Variation in Student Response to an Authentic Research Experience**  
**H.J. Henter,** **M.M. Butler,** and **S.F. Mel.** University of California San Diego, La Jolla, CA.
Authentic research experiences increase student engagement in science. But do these experiences affect every student equally? We examined two factors that could influence the effect of research on student attitudes about science: gender and previous research experience.

We have incorporated an authentic research module into several large courses at UC San Diego. Students are using DNA barcoding to create a species inventory of the Scripps Coastal Reserve. Students are gaining skills in molecular biology and bioinformatics while adding novel data to the Barcode of Life Database and establishing baseline ecological data for future conservation efforts.

We used a pre/post survey design to quantify how student attitudes changed over the quarter that included authentic research. The survey was developed by the authors to address the specific goals of this project. A priori, we categorized questions into 5 topics: excitement about research, interest in collaboration, tolerance of ambiguity, environmental engagement, and students’ perception of themselves as scientists.

We determined that across all questions, the attitudes of female students changed more than the attitudes of male students (F(1,25)=15.2, p<0.0006). The attitudes of females and males did not differ at the beginning of the quarter, but female students had a greater increase in the attitudes about science we hope to foster. We also determined that students’ perception of themselves as scientists increased the most for those with the least amount of prior research experience (F(1,8)=6.9, p<0.03). Students who had not done research started the quarter with a lower perception of themselves as scientists (F(1,8)=25.0, p<0.001). Previous research experience did not affect student responses in the other categories of questions.

In conclusion, students do vary in the way that research alters their attitudes. These results indicate that certain groups of students may benefit more from research than previously recognized. We are currently conducting focus groups to gain a more qualitative understanding of this variation.

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

**8-B**  
**Student Reaction to Nontraditional Teaching in a Test of CREATE on Seven Campuses**  
S.G. Hoskins1 and L.M. Stevens2. 1 City College of the City University of New York, New York, NY; and 2 University of Texas at Austin, Austin, TX.

There is general agreement that traditional classroom approaches fall short in supporting learning, but student resistance to change may discourage innovation, especially for faculty assessed only by student post-course evaluation. Concerns about negative student reaction may thus affect faculty willingness to apply evidence-based nontraditional strategies.

We use intensive analysis of primary literature to demystify and humanize science through the CREATE (Consider, Read, Elucidate hypotheses, Analyze/interpret data, and Think of the next Experiment) strategy. In a 2007 expansion of CREATE we trained NY/NJ/PA college faculty who subsequently (2008) taught their own courses using CREATE. We hypothesized that students of these first-time CREATE implementers (CIs) would have an overall positive reaction to CREATE. Such reaction could support students’ learning by influencing their motivation, while also facilitating expanded use of this nontraditional strategy on the implementers’ campuses.

We tested the hypothesis by including a survey of student reaction to CREATE as one of a suite of cognitive/affective assessments used by the PIs and the study’s Outside Evaluator (OE). We also followed up with CIs 5 years later regarding potential expanded use of CREATE on their campuses. The OE collected 104 open-ended written student responses to the prompt: “How do you feel about the CREATE method of instruction and your learning in this course?” A total of 79% of responses were positive (range: 70–100% on individual campuses). Positive comments fell into 14 categories. Negative comments were seen in three categories, each of which (e.g. concept mapping) was also mentioned by other students as a positive. Thus in all seven implementations, students’ overall response to CREATE was positive. CIs continue to use CREATE and, on multiple campuses, additional faculty now use the strategy for other courses. We conclude that student reactions to their first exposure to nontraditional CREATE teaching are overall positive, potentially supporting both learning and the adoption of CREATE strategies by additional faculty. We thank NSF for support through DUE 0618536.

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

**9-A**  
**A Large Course Redesign of a General Microbiology Lecture Course Incorporating a Student-Centered Active Learning Environment with Upside-Down Pedagogies (SCALE-UP)**  
A.M. Lee, M.G. Keen, T.I. Petty, M. Miller-Kittrell, and J.M. Bradshaw. North Carolina State University, Raleigh, NC.

At North Carolina State University, the General Microbiology lecture was a large-enrollment (>1000 students/ year), critical-path course taught year-round in multiple sections by different instructors. Large lecture halls with one instructor delivering a passive lecture were the standard model of instruction. As expected, this environment leads to passive learners; students receive information and internalize it by memorization. In order to improve the stu-
In 2013, the CLASS (Colorado Learning Attitudes about Science Survey) was used to evaluate attitudes regarding problem solving before and after each semester. Pre-course surveys showed low confidence in problem solving ability. I hypothesized that a combination of low confidence and lack of specific instruction on problem-solving techniques in prior coursework led to these issues. I used explicit instructional techniques including peer and expert examples and non-examples for student assessment of techniques, step-by-step demonstrations, and practice with specific skill components throughout the semester to improve both skill and confidence. The average score on the complex homework problems was 85%, with an average improvement of 12% over the semester (N=11). The CLASS survey was re-administered at the end of the course to identify whether confidence had changed over the semester. As sample sizes are small and data collection continues this semester, statistical analyses (one-way ANOVA for problem solving and paired t-test for confidence) will be presented on the poster at the conference to identify whether these gains are significant.

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

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

**11-A**

**Effects of a Classroom-Based Authentic Research Experience on Learning Genetics Concepts**

C.A. MacKinnon and J. Cuellar Fuentes. University of the Incarnate Word, San Antonio, TX.

While recent reports suggest that authentic research improves STEM education, classroom-based research projects are difficult to implement and their effectiveness for improving student learning in specific disciplines needs further study. Our hypothesis is that students who first experience a classroom-based authentic research project (ARP) retain knowledge of genetics concepts better than students who first experience a traditional laboratory project (TLP). Study participants were enrolled in different sections of an upper division Genetics & Lab course. Study participants were assigned to two treatment groups. Treatment A students (n=8) first conducted an ARP involving gene annotation of a *Drosophila biarmipes* contig. Treatment B students (n=8) first conducted a TLP involving an electrophoresis analysis of different hemoglobin proteins coupled with a genomic database activity that explored variants of the hemoglobin gene. Students’ knowledge was assessed at the start (pre), mid-term (mid), and end (post) of the semester using modified versions of the Genetics Concepts Assessment Test (GA) and the Genomics Education Partnership Annotation Quiz (GEP). The percent of correct answer scores subjected to a one-way analysis of variance with GEP as the response, Treatment as a fixed factor, and Assessments as the repeated-measures factor produced
a $p$ value of 0.0947, i.e., at a significance level of 0.10, the TLP students scored consistently higher on the GEP than the ARP students. However, 90% simultaneous confidence intervals showed that the means of the pre, mid, and post scores between ARP and TLP groups were not statistically different. A one-way analysis of variance with GA as the response, Treatment as a fixed factor, and Assessments as the repeated-measures factor produced a $p$ value of 0.6418, i.e., there was no statistical significance in mean GA scores between treatment groups. These results show that an initial ARP in a course curriculum did not result in increased learning of genetics concepts. However, the 3-week length of the research project may have limited the learning impacts and the sample size was small.

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

12-B  
**Outcome-Based Method to Assess Student Learning over Different Timescales**  
**J. Moberg-Parker, D. Pires, C. Shapiro, M. Levis-Fitzgerald, and E.R. Sanders. University of California Los Angeles, Los Angeles, CA.**

Studies have shown that science majors enter into their introductory science coursework with misconceptions about evolution and natural selection, which may affect their ability to understand and apply evolutionary concepts to their daily life and education. Teaching this topic over a single chapter or course module generally does very little to mitigate student misconceptions. We tested the hypothesis that repeated exposure to the process of natural selection over the duration of an introductory course will increase students’ conceptual understanding of evolution and their mastery of related key concepts pertaining to natural selection. A pedagogical intervention consisting of question progressions relevant to evolutionary concepts was designed to help students apply and integrate evolution as a governing principle across the course. The intervention was assessed by administration of the Conceptual Inventory of Natural Selection (CINS) Pre/Post course. Students made significant ($p<0.01$) learning gains of 15–50% for 9 out of 10 concepts related to natural selection. Analyses also revealed the achievement gap between URMs and non-URMs was markedly reduced, but further study is required to determine whether these gains correlate to the pedagogical intervention. The CINS was administered to students in upper division courses approximately half a year later to assess retention of evolutionary concepts. We found that the structured pedagogical intervention resulted in greater retention of learning overall, with significant ($p<0.01$) retention in 2 out of 10 concepts related to natural selection, when compared to a non-intervention group. Together these results indicate that more student-centered strategies improve both learning and knowledge retention, and that the assessment instrument can be used over different timescales. Based on these results, further curricular assessment will include the use of other concept inventories. For example, the inclusion of the Genetics Concept Inventory for the assessment of a flipped course format and its impact on student performance in introductory and advanced level courses.

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

13-A  
**The Emerging Microbe Project: Synthesis of Pathogen Identification and a Clinical Case Study in a Doctor of Pharmacy Infectious Disease Course**  
**L.A. O’Donnell, M.W. Perry, and D. Doup. Duquesne University, Pittsburgh, PA.**

For many doctor of pharmacy (PharmD) students, basic sciences and clinical pharmacy often appear disconnected. In the infectious disease field, PharmD students additionally struggle with mastering the diversity of microorganisms and the corresponding variety of therapies. The objective of this study was to design an interdisciplinary project that would integrate fundamental microbiology with clinical research and decision-making skills. The Emerging Microbe Project guided students through patient cases from the first stages of microbe identification via sequence analysis to defending a therapeutic strategy for an infected patient in a case study. The unknown pathogens were selected because they had not been seen in the classroom or in the students’ clinical practice sites, so pathogens and corresponding therapies were new to the students. We hypothesized that the students would develop a better understanding of how microbiology fit into clinical practice and that they would gain confidence and skill in independently selecting appropriate anti-microbial therapies for a new disease state. We demonstrate that the Emerging Microbe Project significantly improved student learning through multiple assessment strategies and increased student confidence in their clinical infectious disease skills. Direct evidence of student learning was assayed through a microbiology report, a care plan, and through exam questions before and after the project. Students demonstrated substantial improvement in mastering learning objectives (average individualized learning gain=0.38, $p<0.001$) as measured by exam scores. Evidence of student learning was also acquired through pre- and post-assessment surveys to gauge students’ perception and confidence in mastering the learning objectives, with students reporting increased confidence in researching unknown infectious disease states and in using validated infectious disease resources to design care plans. The Emerging Microbe Project represents one mechanism by which pharmacy students can develop the necessary independence and proficiency for a successful pharmacy career.
14-B

Immunological Tools: Engaging Students in the Use and Analysis of Flow Cytometry and Enzyme-Linked Immunosorbent Assay (ELISA)

L.E. Ott and S. Carson. North Carolina State University, Raleigh, NC.

In an effort to provide the student population of North Carolina State University with exposure to flow cytometry and ELISA, we designed a novel half-semester course that focused on introducing students to applications, experimental design, and data analysis aspects of these techniques. We hypothesized that the course student learning outcomes (SLO), which included higher-order skills defined by Bloom’s Revised Taxonomy (BT), would be attained upon completion of this course. The SLOs for this course were to: identify applications of flow cytometry and ELISA and compare to other techniques (BT analyze), describe how a flow cytometer operates, design and troubleshoot flow cytometry experiments (BT evaluate and create), analyze flow cytometry data (BT analyze), compare different types of ELISA (BT analyze), design and troubleshoot ELISA experiments (BT evaluate and create), and analyze ELISA data (BT analyze). Undergraduate (n=23) and graduate (n=18) students from varying educational levels and disciplines were enrolled in this course, which was offered over the period of three semesters and consisted of weekly lecture and laboratory sessions. In the laboratory sessions, students performed and/or analyzed data from three separate laboratory exercises: identification of transgenic zebra fish hematopoietic cells, analysis of transfection efficiency, and analysis of cytokine production upon LPS stimulation. Students were formally assessed by multiple means, including lab report 1 (zebra fish; 87.6% average for all semesters), lab report 2 (transfection; 82.8%), lab report 3 (LPS; 89.6%), data analysis laboratory practicum (87.8%), and cumulative final exam (80.9%). The course instructor (L.E.O.) performed all grading in the course. Further, an anonymous student self-assessment administered at the beginning and end of the course revealed increased student confidence in the knowledge and skill sets defined in the SLOs. These data demonstrate that the course SLOs were attained and supports the incorporation of flow cytometry and ELISA into the laboratory components of higher education life science and engineering curricula.

15-A

Using Community Partners to Effectively Engage Students in Microbiology Research

K.A. Page. Southern Oregon University, Ashland, OR.

Significant research experience is a desirable, and often mandatory feature of undergraduate Biology and Microbiology degree programs. It is difficult to provide all students with research experience at universities that have high student-faculty ratios or limited facilities. At Southern Oregon University, community partners are leveraged to provide undergraduates with applied research projects. Partnering with the State Department of Environmental Quality (DEQ) and local government officials has resulted in a win-win-win situation for students, faculty, and the community. Students gained valuable research experience, the faculty burden of supervising multiple student research projects was lessened, and the DEQ completed community projects that would have been impossible without volunteer student researchers. I investigated whether students who completed DEQ research projects were able to demonstrate proficiency in experimental design, data collection, data analysis, and presentation as well as students who worked on non-community oriented projects. The quality of student DEQ research projects was assessed and compared to the quality of student research projects carried out under Biology faculty mentors without involvement of a community partner. An assessment rubric was used to score 23 student presentations of on-campus research projects and 8 presentations of DEQ-based projects. To reduce bias, each presentation was scored by an average of 5 different faculty members. Mean scores were only slightly higher for students who did DEQ research and statistical tests failed to reveal significant differences between the two groups of students. The assessment indicated that students who completed DEQ research projects gained effective research experience. Results from projects such as identification of microbial pollution sources, effects of irrigation water on stream quality, and monitoring of water recreation sites were highly beneficial to the community as they were used to guide local watershed management decisions.

16-B

Do Student-Generated Visual Models Promote Learning because They Are Active, Visual, or Both?

K.J. Quillin. Salisbury University, Salisbury, MD.

Student drawings have been recognized as an important learning strategy in science (e.g. Ainsworth et al., 2011, NAS 2011). For example, drawings can promote model-based reasoning, which is one of the six Vision and Change core competencies (AAAS, 2009). Does the creation of visual
It was hypothesized that if students were trained to evaluate implemented throughout the writing and revision process. Llized peer critiquing and assessment in a group setting was original data sets. A student-centered approach that uti- developed an original question via a guided exploration information to produce an original scientific paper. Students and guide them through reading, analyzing, and synthesizing all students were given a pre-test consisting of ten multiplechoice questions, and an immediate post-test with the same questions, and were invited to comment on their experi- ence. The learning gain for each student was calculated as 100*(post–pre)/(100–pre). The average learning gains for the four groups (mean ± SE) were passive verbal = 14 ± 4.7%, N = 35; active verbal = 11 ± 5.0%, N = 34; passive visual = 21 ± 7.7%, N = 34; and active visual = 4 ± 7.5%; N = 37. The hypothesis was not supported by the data because there was no significant difference in learning gains among the four groups (p>0.10 for all pairwise t-tests). Further, the active + visual group appeared to struggle the most, not the least. This negative result produced two insights. First, time matters: the time-on-task was held constant for all four groups, meaning that a student in the read-only group could reread a passage several times while some drawing students had insufficient time to process the assignment. Second, training matters: students in the drawing group were least familiar with this learning strategy and appeared to use their time and cognitive resources inefficiently, requesting more instruction. It is predicted that students with sufficient time and training will improve their ability to learn by drawing.

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

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

### 17-A

**Teaching Scientific Writing and Reasoning using Peer Assessment**

I.K. Reed, C.A. Millard, D. Carillo, and S.J. Pearlman. University of Saint Joseph, West Hartford, CT.

Scientific writing fuels the dissemination of knowledge in the field of biology, yet many students struggle with articulating the scientific method through writing. A course was developed to introduce students to scientific literature and guide them through reading, analyzing, and synthesizing information to produce an original scientific paper. Students developed an original question via a guided exploration of literature, and authored a scientific report based on a central hypothesis, integration of primary literature, and original data sets. A student-centered approach that utilized peer critiquing and assessment in a group setting was implemented throughout the writing and revision process. It was hypothesized that if students were trained to evaluate the work of others using a standardized rubric they would gain a better understanding of how writing is assessed, which would lead to improvements in their own approach to writing. Each student also submitted a justification for assigning a particular grade, and these justifications were assessed by the instructors. Outcomes were measured using student self-assessments, weekly reflections and course performance. Data indicated that students gained significant knowledge in key skill and content areas including writing the sections of a scientific report, reading and analyzing scientific literature, use of a standardized rubric, and peer assessment of scientific writing (from little knowledge to very knowledgeable, Likert scale, self-reported by students). In addition, students felt that working in a group facilitated multiple perspectives, helped develop strategies for solving conflicts, aided in identifying weaknesses within their own writing, and increased confidence in public speaking and justification of arguments. A clear trend in writing quality was observed through grade analysis, and average assessment grades improved by a full letter by the end of the course (from C+ to B+ average). In conclusion, peer assessment resulted in improved writing skills, increased self-awareness during the writing process, and an enhanced understanding of scientific literature.

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

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

### 18-B

**Increases in Core Concept Knowledge within a Comparative Genomics Multi-Section Introductory Laboratory Class**

H.N. Rowedder, C.M. O’Connor, and D.M. Warner. Boston College, Chestnut Hill, MA.

The Boston College Biology Department has a three-credit sophomore-level laboratory course, which we have engineered to engage large numbers of undergraduate students in authentic research projects. For the scientific project, students study the phylogenetic conservation of the enzymes involved in methionine biosynthesis. Conservation of MET gene function is tested by cross-species plasmid complementation of *Saccharomyces cerevisiae* MET deletion strains. We hypothesized that adopting an advanced lab class format for introductory students would improve students’ understanding of core concepts of the molecular cell biology lab including structure-function relationships, information transfer, metabolism, and molecular evolution. Scientific writing was emphasized by: 1) using the CREATE method (Hoskins et al., 2007) to analyze pieces of a journal article while performing similar experiments in the laboratory; and 2) writing a series of mini-reports that culminated in a final manuscript detailing the student’s semester-long projects. Pre- and post-course evaluation instruments include concept tests and student self-assessed confidence and
learning gains. Comparison of pre- and post-course scores of over 350 students on a 20-question concept test showed an average increase of 6.35 correct answers (8.7/20 to 14.9/20), with consistency across multiple semesters. These post-course scores correlated with final grades. Interestingly, self-assessed confidence gains showed no correlation to final course grades. We found that adoption of a semester-long project narrative, emphasizing scientific communication, correlated with significant increases in core knowledge. This research project was deliberately designed to have a flexible format that could be easily adopted for metabolic pathways in other genetically-tractable organisms with sequenced genomes. Course materials are freely available on a website.

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

**19-A**

This Flippin’ Class: Attitudes About Learning in a Flipped Microbiology Classroom.  
H.M. Seitz. Johnson County Community College, Overland Park, KS.

The flipped classroom has been shown to be an effective way to engage students and deliver active learning. The flipped classroom is described as delivering the majority of course content outside of class and using class time to develop higher levels of understanding of the content and spend time solving problems in the course. Since introducing the flipped model into a pre-allied health microbiology course, course evaluations have been mixed. The purpose of this study was to understand why a large number of students in the course had a negative attitude about the flipped course method. Students who have been previously successful in traditional classroom environments seemed to have the most problems with the flipped classroom. Therefore my hypothesis was that students with higher GPA coming into the course would have a more negative attitude about the course format than students with a lower GPA. To explore attitudes about the course, students (n=112) were asked four times throughout the semester to rate their attitudes on a 1-to-10 scale about in-class activities, working with teams in class, as well as the helpfulness of in-class discussions on their learning. The data suggests that indeed students with higher GPAs start with a more negative attitude about the flipped classroom compared with students with a lower GPA. When students were asked how much they enjoyed the flipped classroom the average response on the first survey was 5.5 for higher GPA and 7.5 for lower GPA. In addition, attitudes about the course improved throughout the course for both groups. However the students with a lower GPA retained a much more positive attitude about the course than students with a higher GPA (the 4th survey had an average response of 6.7 for higher GPA and 8.4 for lower GPA). Interestingly, attitudes did not predict success in the course as students coming into the class with a higher GPA maintained their high grades even with a more negative attitude. This study suggests that students who are successful coming into the class may not see the benefit of a flipped classroom model, and that the negative attitude they have to start the course may persist throughout the semester.

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

**20-B**

Bacteria in the Dirt: An Inquiry-Based Lab Curriculum in the First Biology Core Course  
A. Shanmuganathan. Washington & Jefferson College, Washington, PA.

To go from ‘Vision’ to ‘Change’, an inquiry-based laboratory curriculum with a semester-long research project was implemented in an introductory biology course for science majors. Students characterized soil bacteria at a Field Station, proximal to a Marcellus shale gas drilling pad. Students worked in small groups and were involved in all stages of the project – from constructing the hypothesis to poster presentation. It was hypothesized that this lab would result in greater student engagement while also allowing for conceptual mastery. After two years of implementation (n=183), effects on student attitudes to science and on learning were assessed. Mean scores on quizzes that tested conceptual mastery, administered at the end of the semester (post- quiz), were higher than those of quizzes administered during the course of the semester (pre-quiz) [mean (post) = 11.23; mean (pre) = 9.68]. The increase in means was statistically significant (paired two-sample t-test, p=3.51 x 10^{-15}), indicating that the curriculum was effective in improving student learning. Students’ attitudes to science and learning gains were assessed using CURE surveys (Grinnell College) that compare students in this study with all students undertaking course-based research in various institutions [n(other)=7364]. Attitude to science was determined by responses to 5 questions including ‘Even if I forget the facts, I’ll still be able to use thinking skills learned in science’ and was expressed on a scale of 1 (strongly disagree) to 5 (strongly agree). A mean attitude score of 3.97 was comparable to the other students’ score of 4.05. Students also self-reported their learning gains in 21 areas including ‘tolerance for obstacles faced in research’ on a 1-to-5 scale, with 5 being the largest mean. Mean ratings for learning gains was found to be 3.7, significantly higher (two sample t-test, p=9.97 x 10^{-6}) than the 3.31 score reported for other students. It can be concluded that this inquiry-based laboratory was effective in improving student engagement and learning and could potentially serve as a prototype for implementing similar laboratories in other courses.
Selective Flipping: A Problem Solving-Based Approach to Teaching DNA Replication
A. Shanmuganathan. Washington & Jefferson College, Washington, PA.

The intricacies of DNA replication in prokaryotes and eukaryotes are difficult and yet crucial for students to master. To achieve better student learning and engagement, flipping the instruction is an option. But, would selective 'flipping' of difficult topics be conducive to student learning? To investigate this, flipped instruction of DNA replication was implemented in an introductory biology course taught to science majors. It was hypothesized that flipping the classroom, by substituting lecturing with problem solving, would improve student learning. To test this, DNA replication was taught to two sections of students using the traditional lecture style \[ n(T)=61 \] and to another section of students in the flipped style \[ n(F)=34 \].

The flipped class viewed a video lecture on the topic before the start of class. In class, students worked in small groups on instructor-developed problem sets relevant to the topic. The instructor discussed the problems and provided cues and answers. Student learning was assessed using performance on a multiple-choice exam consisting of 16 questions of which 7 required higher-order cognitive skills (HOCs). It was found that the mean exam score of the students in the flipped class was 4.4% points higher than the mean exam score of the students in the traditional class \( \text{mean}(F)=12.62 \) vs. \( \text{mean}(T)=11.92 \). However, the difference in means was found to be statistically insignificant \( (\text{two sample } t\text{-test}; p=0.254) \). Considering the mean scores in the HOCs questions among the two groups, the students in the flipped class performed better and the difference in means was found to be statistically significant \( (\text{two sample } t\text{-test}; p=0.038) \). Besides the mean scores, the proportion of students earning an A or B grade was also considered. In the flipped class, 60% of students earned As and Bs compared to 48% of the traditional class, which was statistically significant \( (z\text{-test}; p=0.597) \). While the study is worth repeating with different assessment methods, the results show that selective flipping of difficult biology topics is at least as favorable to student learning as traditional classes and imparts better HOCs and could be implemented more often in introductory biology courses.

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

22-B
Mining Concept Inventory Data For Student Alternate Conceptions
A.C. Smith, S. Balcom, J. Buchner, V. Briken, J. Destefano, B. Frederiksen, S. Hutcheson, N. El-Sayed, K. Frauwirth, V. Lee, G. Marbach-Ad, K. McIlver, D. Mosser, P. Shields, W. Song, D.C. Stein, R. Stewart, K. Thompson, S. Yarwood, and B. Quimby. University of Maryland, College Park, MD.

The Host Pathogen Interactions Concept Inventory (HPI CI) consists of 18 multiple-choice questions validated through an iterative process \( (\text{Marbach-Ad et al. 2009, 2010}) \). After students answer each question, they are asked to write an explanation for their response. We suggest that reviewing students’ open-ended explanations to HPI CI responses will allow definition of student alternative conceptions \( (\text{ideas that differ from valid scientific explanations}) \) that will serve to inform faculty involved in curriculum development. The HPI teaching team \( (20 \text{ research and teaching faculty}) \) have developed a method to mine HPI CI data for alternative conceptions. This process involves working in teams to read student responses, developing statements that define common problems in student thinking, grouping these together to define a set of codes and then using that code book to quantify the prevalence of the codes in the data set. We will report on the analysis of one question that targets student understanding of antibiotic resistance. Comparing analysis of student explanations to CI responses on pre-course vs. post-course implementation of the CI \( (~800 \text{ responses from students in introductory microbiology}) \) we defined 20 alternative conception codes. We quantified the prevalence of the codes in the data set and determined the codes that were most frequent. We then collapsed the coding into larger categories. Categories most resistant to change from our teaching efforts included “Antibiotics cannot be degraded by bacteria – not a possible mechanism for resistance” \( (17.9\% \text{ of responses pre-course to 15.6\% post-course}) \), “Gene expression cannot change in response to antibiotics or other environmental factors” \( (17.9\% \text{ of responses pre-course to 26.6\% post-course}) \), Selective growth is not necessary for evolution \( (7.1\% \text{ of responses pre-course to 7.4\% post-course}) \). Our approach allows us to uncover student alternate conceptions and serves as a “bridging the gap” exercise that informs faculty about the distinctions in their way of thinking in comparison to student or novice thinking.

ASM Curriculum Guideline Concept(s): Evolution, Advancing STEM education and research
Pedagogical Category(ies): Student learning
23-A  
Effects of In-Class Group Problem Sessions on Group Studying  
K.E. Tifft, M. Reese, and E.J. Fisher. John Hopkins University, Baltimore, MD.  

Due to the clear benefits of collaborative learning, we encourage students in our large biochemistry lecture course to study in groups. However, our anecdotal observations indicated that students use traditional study methods instead of more active methods, including group studying. We hypothesized that in-class group problem sessions would increase the use of and/or attitudes about group studying. In fall 2013 we implemented two in-class problem sessions with 265 students randomly assigned to groups of 5. We evaluated studying behavior and attitudes using a survey of study habits given to students at the beginning (pre-) and end (post-) of the semester and to alumni (2012) who did not participate in the in-class problem sessions.  

Consistent with our previous observations, less than half of students regularly study with others. Of the 2012 students surveyed (n=173), 42% regularly used group studying and 56% thought that group studying was effective. Use of group studying in 2013 was similar to 2012 (41% pre-survey, n=167) and did not increase during the semester (41% post-survey, n=116). Similarly, perception of group studying effectiveness did not change significantly from 2012 or over the semester (52% pre-survey, 51% post-survey). The reported use of group studying did not correlate with higher course scores for either group. On surveys about the problem sessions 58% (n=242) and 48% (n=226) of students rated the first and second problem sessions, respectively, as effective. The majority of students (84%, n=242) support more problem sessions in the future.  

In conclusion, ~40% of biochemistry students regularly use group studying. Interestingly, 10–15% of students don’t regularly participate in group studying, but think it is effective. Although student responses to the in-class problem sessions were quite positive, the problem sessions did not significantly affect short-term behavior or attitudes on group studying. These results will inform our efforts to revise the biochemistry course to encourage collaborative learning inside and outside of class.  

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

24-B  
Improvement in Data Interpretation Skills through Student-Centered Tutorials with Direct Assessment  
H. Verkade. Monash University, Melbourne, Australia.  

Despite requiring skills in critically interpreting and evaluating presented scientific data, many students skip the results section of a journal article and instead rely solely on the authors’ conclusions. This study examined methods to re-focus final-year biological science students onto the results of a paper, rather than the discussion. Two activities were introduced into the unit/subject: 1. Journal club presentations (un-assessed) given by the lecturers. 2. Interactive tutorials in which students discussed and presented their interpretation of the results from journal articles. The tutorials were directly assessed in questions on the final exam. The hypotheses for this study were that these activities would improve students’ 1) attitudes towards scientific data, 2) confidence in interpretation of data, and 3) skills in data interpretation, by repeated exposure to results interpretation, opportunities for practice, and the motivation of directly aligned assessment. Their attitudes and confidence were assessed in pre- and post-surveys and their skills assessed with embedded pre- and post-tests on simple molecular genetics data interpretation. The students showed no significant changes in either their confidence in reading journal articles or interpreting data, but did improve in their attitudes toward the fallibility of published scientific research (p = 0.821, 0.829, 0.133, 0.039*). Interestingly, they showed a significant increase in the accuracy, precision, and use of statistics in their answers to simple molecular genetics data (p ≤ 0.016*). A total of 76% reported that the student-centered tutorials were valuable learning activities, while only 27% thought this of the lecturer-centered journal club presentations. In conclusion, students’ abilities in data interpretation have increased in this class, in which we used student-centered tutorials coupled with the motivation of direct assessment of data interpretation skills. This improvement was not reflected in improved confidence towards reading journal articles based on standard survey questions, and there is no comparable control group without these interventions.  

ASM Curriculum Guideline Concept(s): Learning Skills and Mastery of Microbiology  
Pedagogical Category(ies): Course design, Student learning  

25-A  
Promoting Metacognition to Improve Studying and Learning Skills and Mastery of Microbiology  
T.D. Westbay. St. John Fisher College, Rochester, NY.  

This work is motivated by a desire to empower students and help them acquire the tools and confidence necessary to be successful in challenging science classes. Operating on the premise that effective learning involves metacognition (thinking about one’s own thinking and learning) and that metacognitive skills can be taught, structured self-reflective activities in the form of exam wrappers were incorporated into BIOL 214, a required general microbiology class. The exam wrappers consist of two parts. Before each exam, students answer survey
questions documenting how they prepared. After receiving their graded exams, students are guided through an analysis of missed questions and then reflect in writing regarding the reasons for their incorrect answers, what improvements they need to make in order to avoid those pitfalls in the future, and the specific actions they will take in preparing for the next exam. The hypothesis being tested is that engaging in self-reflective practice will result in positive changes in studying and learning habits and improved learning by comparison with semesters where structured self-reflection was not a formal course component. Among the students engaging in structured self-reflection (n=46 students), 70% reported changing their preparation for exams after exam 1. The nature of some of these changes included students creating their own study materials (70% of students for exam 1 compared with 84% for exam 3) and increased time spent in exam preparation (54% of students reported spending 6 or more hours preparing for exam 1 compared with 74% of students preparing for the final exam). Student performance on the comprehensive final exam is consistent with improved student learning. In the classes including structured self-reflection, 49% of students correctly answered at least 80% of the questions on the comprehensive final exam compared with 35% of students in the previous semester (n=57 students). Data from the current spring 2014 offering of BIOL 214, which continues to incorporate structured self-reflection, and qualitative data tracking the changes in behavior of select individual students, will also be included.

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

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

### INDEX BY CONTENT

**Advancing STEM education and research**

- Barrette-Ng, I.H. ........................................... 1-A
- Bates, T.C. .................................................. 2-B
- Dinsdale, E.A. ............................................. 3-A
- Gregg-Jolly, L.A. ......................................... 6-B
- Henter, H.J. ................................................. 7-A
- Hoskins, S.G. .............................................. 8-B
- Lee, A.M. ..................................................... 9-A
- Leonard, M. ................................................. 10-B
- MacKinnon, C.A. ........................................... 11-A
- Moberg-Parker, J. ........................................ 12-B
- Ott, L.E. ..................................................... 14-B
- Quillin, K.J. .................................................. 16-B
- Reed, I.K. ..................................................... 17-A
- Seitz, H.M. .................................................... 19-A
- Shanmuganathan, A. ..................................... 21-A
- Smith, A.C. ................................................... 22-B
- Tifft, K.E. ..................................................... 23-A
- Westbay, T.D. ................................................. 25-A

### Evolution

- Moberg-Parker, J. ........................................ 12-B
- Rowedder, H.N. ........................................... 18-B
- Smith, A.C. ................................................. 22-B

### Impact of microorganisms

- Dinsdale, E.A. ............................................. 3-A
- Furlong, M.A. .............................................. 5-A
- O’Donnell, L.A. ........................................... 13-A
- Page, K.A. ..................................................... 15-A

### Information flow

- Fox, D.F. ..................................................... 4-B
- Reed, I.K. ..................................................... 17-A
- Seitz, H.M. .................................................... 19-A

### Pathways

- Rowedder, H.N. ........................................... 18-B
- Verkade, H. .................................................. 24-B

### Structure and function

- Fox, D.F. ..................................................... 4-B

### Systems

- Verkade, H. .................................................. 24-B

### INDEX BY PEDAGOGY

**Course design**

- Barrette-Ng, I.H. ........................................... 1-A
- Bates, T.C. .................................................. 2-B
- Lee, A.M. ..................................................... 9-A
- MacKinnon, C.A. ........................................... 11-A
- Ott, L.E. ..................................................... 14-B
- Rowedder, H.N. ........................................... 18-B
- Seitz, H.M. .................................................... 19-A
- Tifft, K.E. ..................................................... 23-A

**Hands-on projects**

- Dinsdale, E.A. ............................................. 3-A
- Furlong, M.A. .............................................. 5-A
- O’Donnell, L.A. ........................................... 13-A
- Ott, L.E. ..................................................... 14-B
- Page, K.A. ..................................................... 15-A
- Shanmuganathan, A. ..................................... 21-A

**Student learning**

- Dinsdale, E.A. ............................................. 3-A
- Fox, D.F. ..................................................... 4-B
- Gregg-Jolly, L.A. ........................................... 6-B
- Henter, H.J. .................................................. 7-A
- MacKinnon, C.A. ........................................... 11-A
- Moberg-Parker, J. ........................................ 12-B
- O’Donnell, L.A. ........................................... 13-A
- Ott, L.E. ..................................................... 14-B
- Quillin, K.J. .................................................. 16-B
Smith, A.C. ...................................... 22-B
Tifft, K.E. ........................................ 23-A
Verkade, H. ...................................... 24-B
Westbay, T.D. .................................... 25-A

Teaching approaches
Hoskins, S.G. ...................................... 8-B
Leonard, M. ........................................ 10-B
Reed, I.K. .......................................... 17-A
Seitz, H.M. ........................................ 19-A
Shanmuganathan, A. ............................... 20-B

INDEX BY AUTHOR
Barrette-Ng, I.H. .................................. 1-A
Bates, T.C. ........................................ 2-B
Dinsdale, E.A. ...................................... 3-A
Fox, D.F. .......................................... 4-B
Furlong, M.A. ...................................... 5-A
Gregg-Jolly, L.A. .................................. 6-B
Henter, H.J. ........................................ 7-A
Hoskins, S.G. ...................................... 8-B
Lee, A.M. .......................................... 9-A
Leonard, M. ........................................ 10-B
MacKinnon, C.A. .................................. 11-A
Moberg-Parker, J. ................................ 12-B
O’Donnell, L.A. ................................... 13-A
Ott, L.E. .......................................... 14-B
Page, K.A. ........................................ 15-A
Quillin, K.J. ....................................... 16-B
Reed, I.K. .......................................... 17-A
Rowedder, H.N. .................................. 18-B
Seitz, H.M. ........................................ 19-A
Shanmuganathan, A. ............................... 20-B
Shanmuganathan, A. ............................... 21-A
Smith, A.C. ...................................... 22-B
Tifft, K.E. ........................................ 23-A
Verkade, H. ...................................... 24-B
Westbay, T.D. .................................... 25-A