SABER 2014
Abstract Booklet

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Please note:

This year we used a new software program for abstract submissions. This program gives all abstracts a number based on order of submission.

However, your abstract number is NOT your poster number.
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2. Student content knowledge in biology and longitudinal performance in STEM courses increase in response to higher-level oral assessments

Douglas Luckie*, Michigan State University; Aaron Rivkin, Michigan State University; Jacob Aubry, Michigan State University; Benjamin Marengo, Michigan State University; Leah Creech, Michigan State University; Ryan Sweeder, Michigan State University

The literature suggests that exams and other high stakes assessments tend to drive student learning in the classroom (Tobias 1992, Tobias and Raphael 1997). We tested a hypothesis that students would raise their efforts at meaningful learning, if they were to be assessed in an explicitly meaningful manner. An optional verbal final exam in an introductory biology course was used to provide an alternate venue for assessing student understanding. Students who opted for and passed a verbal final (VF) exam outscored their peers (66.4% n=160, 62% n=285, respectively; $p < 0.001$) on a content exam built with forty Medical College Admissions Test (MCAT) questions. The higher achieving students performed better on MCAT questions in all topic categories. Student who participated even once, but did not pass the VF, made gains in performance on both the MCAT assessment and traditional final exam. Participation in the VF exam came from a wide range of students not just the academically elite. Participation and success passing the verbal final exam had a range of representation in terms of academic standing, gender, and ethnicity. Whether they participated or not, students nearly unanimously (92%) strongly valued the option. In longitudinal studies, a student's success on the verbal final exam in introductory biology also correlated with enhanced success in multiple subsequent upper-level science courses, with greatest significance in biochemistry, physiology and organic chemistry. Our findings suggest oral exams at the introductory level may allow instructors to assess and aid students striving to achieve higher-level learning.

3. Understanding genetic inheritance: A learning progression of pre-service elementary teachers

Jingjing Ma*, Texas Christian University

Learning progressions (LPs) are theoretical frameworks that describe successive developmental levels of learners' conceptual understanding about a concept, topic, or domain over time. Multiple studies show that American students in primary and secondary grades, even in adulthood are lack of adequate understanding or hold misconceptions of genetic inheritance. Since LPs are heavily dependent on instructional practices, this study examines a learning progression of genetic inheritance of preservice elementary teachers in a sophomore undergraduate classroom (17 students) based on the conceptual frameworks of LP in genetics

developed by Elmesky (2012). Pre-test and post-test of understanding in genetic inheritance are conducted before and after a one-week instruction (two periods). During the instruction, multiple representations of genetics are presented in class. Preliminary data shows the best ways to help preservice elementary teachers develop conceptual understanding of genetic inheritance among the presented representations.

4. Changes in Undergraduate Student Content Knowledge and Research Methods Skills During a Research Course in Molecular Cellular Biology

Todd Reeves*, Northern Illinois University; Larry Ludlow, Boston College; Douglas Warner, Boston College; Clare O'Connor, Boston College

The introductory laboratory course in the Boston College Biology Department involves students in a semester-long research project in the comparative genomics of methionine biosynthesis. The course, which is grounded in active learning theory, introduces students to the core methodologies of molecular cell biology and microbial genetics within the context of the research project. This study examines the extent to which participation in this multi-section course was associated with student growth in content knowledge and research methods skills across four semesters (N~400). The study also examines whether and how student initial status was associated with student characteristics (i.e., major, gender, prior research experience, and year in college) and how student growth was associated with student characteristics, instructor characteristics (i.e., teaching experience, anxiety, and confidence) and classroom practices (i.e., general pedagogical and assessment practices). Objective and self-reported data were collected via online surveys administered to course students and graduate teaching assistants at various points in the semester. Preliminary results from each of the first three semesters have indicated statistically significant growth in objectively measured content knowledge (with ds ranging from .9 to 2.3) and self-reported research methods skills (with ds ranging from .6 to .7). Upon completion of data collection in May, 2014, the cumulative data from four semesters will be analyzed through the estimation of ordinary least squares and multilevel regression models to examine respectively how student variables were associated with student initial status and how student and instructor variables were related to growth. Preliminary results from qualitative analyses of open-ended survey responses suggest the need to provide students with the conceptual background for experiments and the importance of prior biology knowledge for course success.

5. It's All in How you Sell It: Critical Strategies for Improving Performance through Formative Assessments

John Bell*, Brigham Young University; Holli Wiberg, Brigham Young University; Elizabeth Gibbons, Brigham Young University; Jennifer Nelson, Brigham Young University

Helping students learn to solve higher-order problems in biology such as interpreting experimental data is difficult. This challenge is exacerbated by diversity in student learning styles, abilities, and backgrounds. Gains in student performance were observed in both upper and lower division biology courses when the pedagogy included weekly formative assessments. This was true when the course and assessment format contained eight key elements. These essential elements were (1) clever salesmanship from the instructor; (2) creative use of a course pretest; (3) alignment among course objectives, weekly formative assessments, and the final exam; (4) items that require higher-level processing skills; (5) an authentic exam atmosphere during the assessments; (6) immediate and generous feedback following

assessments; (7) motivation to learn from errors through rewards for improvement; and (8) multiple opportunities to revisit difficult concepts from previous assessments to accommodate the diversity of learning trajectories. Student performance on weekly assessments demonstrated that improvement on challenging tasks requires seven or more iterations of exam-like experiences followed by feedback and practice opportunities before maximal learning is achieved. Moreover, the trajectory on this learning curve varied significantly among individual students, and many would have been disadvantaged by a format that included fewer opportunities to iterate the process. Student attitudes toward this sort of course design were favorable. This was especially evident in their perception of the fairness of exams and grading procedures. Post-course interviews with students revealed several important themes regarding their experiences. One was a desire that more courses adopt a similar pattern. Students also reported that multiple failures were often needed before they were willing to identify and correct misconceptions rather than continuing to rely on a less-effective learning strategy.

6. Building skills for complex problem solving through explicit instruction

Maureen Leonard*, Mount Mary University

This study examines the effect of explicit instruction on improving problem solving skills and student confidence in their problem solving ability. Problem solving is a key component in the process of science. The average score on complex problems presented as homework questions in an upper level microbiology course was 75% across 2009-2011. Student evaluations and informal interviews indicated students did not have the skills or the confidence to successfully solve complex problems. In 2012, I implemented a new assessment approach using individualized feedback and targeted interventions for each homework problem. The average score on the same homework problems was 80%, with an average improvement of 4% over the semester (N=39). While encouraging, this was not as large or as fast a gain as desired and student evaluations contained similar comments as before. 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 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 if confidence had changes 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 at the conference to identify if these gains are significant.

7. A Model for Assessing Critical Thinking in an Undergraduate Biology Program

Lacy Cleveland*, University of Northern Colorado; Thomas McCabe, University of Northern Colorado

The United States' competitiveness in scientific innovation is expected to fall over the next decades as a result of an influx of domestically trained STEM workers who lack the proper higher order cognitive skills to perform their jobs. The present study provides a model for and a demonstration of a program evaluation tool that may help biology programs across the United States recognize courses in their programs that are not promoting skills sets demanded in new biology graduates. We aimed to provide a cogent means of biology program self-assessment to identify courses where more emphasis on critical thinking skills is necessary. We used the Blooming Biology Tool to rate course objectives from syllabi and individual test questions representing the past four academic years, 2009-2012, of courses at the University of Northern Colorado's School of Biological Sciences. A Chi-Squared Test of Independence on course objectives did not indicate a difference in the ratio of lower order to higher order cognitive skills across the level of the course; results for test questions are pending. Our preliminary results possibly indicate that desired skills, particularly critical thinking skills, are not being promoted as much as necessary to prepare students' to be successful STEM workers.

8. End of lecture: A meta-analysis of active learning across the STEM disciplines
Scott Freeman*, University of Washington; Sarah Eddy, University of Washington; Miles McDonough, University of Washington; Michelle Smith, University of Maine; Nnadozie Okoroafor, University of Washington; Hannah Jordt, University of Washington; Mary Pat Wenderoth, University of Washington

To test the hypothesis that lecturing maximizes learning and course performance, we meta-analyzed 225 studies that reported data on either exam scores or failure rates when comparing student performance in undergraduate STEM courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on exams and concept inventories increased by 0.49 standard deviations under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). Heterogeneity analyses indicated that both results hold across the STEM disciplines, that active learning increases scores on concept inventories more than on course exams, and that active learning appears effective across all class sizes—although the greatest effects are in small (n ≤ 50) classes. Trim and fill analyses and fail-safe n calculations suggest that the results are not due to publication bias. The results also appear robust to variation in the methodological rigor of the included studies, based on the quality of controls over student quality and instructor identity. This is the largest and most comprehensive meta-analysis of undergraduate STEM education published to date, with results that raise questions about the continued use of traditional lecturing as a control in research studies, and that support active learning as a teaching practice in regular classrooms.

9. Practice Makes Pretty Good: Assessment of Primary Literature Reading Abilities across Multiple Large Enrollment Biology Laboratory Courses
Brian Sato*, UC Irvine; Pavan Kadandale, UC Irvine

Reading primary literature is an essential research skill, and is commonly required in undergraduate biology education. Often however, little time is spent training students how to critically analyze a paper. In order to address whether increasing instruction specifically on how to read a paper would improve transferable skills such as critical thinking, we introduced a primary literature module in three upper division biology lab courses. Instructors conducted class discussions that examined the background, data and conclusions of an article, modeling the approach that researchers take in reading a paper. Student learning was measured by an end of the quarter exam, and we examined overall performance in the assessment exam and performance at specific Bloom's levels to evaluate learning gains. When controlling for factors such as research background, GPA and course grade, we found that this module produced longitudinal learning gains in subsequent lab courses that these students took. These

improvements were not dependent on adhering to a specific method for reading the papers, and were limited to lab courses that included our module, implying that modeling the scientific analysis of primary literature is sufficient to increase comprehension and critical thinking. Interestingly, we found no correlation between previous research experience and exam performance, with students who reported having no research experience performing as well as students with a prior research background. Finally, we documented students' self-reported confidence in their understanding of the paper, and present a model for the relationship between confidence and performance. Overall, our assessment highlights the value of instructor driven discussions of primary literature. Our primary literature module can be easily implemented in both lecture and lab courses, and throughout this session, we will discuss ways in which attendees can adapt our methods to their home institutions.

10. How and why can knowledge of concepts in genetics improve student understanding of concepts in evolution?

Emily Weigel*, Michigan State University; Louise Mead, BEACON Center for the Study of Evolution in Action; Terri McElhinny, Michigan State University

Evolutionary processes are integral to biology, but often misunderstood. Undergraduate biology students' evolution misconceptions are often variable, deeply-rooted, and frequently stem from students' first encounters with evolutionary terms. Because misconceptions can fundamentally impact student understanding of evolution, it is important to understand what information students obtain from courses prior to Evolution. This is particularly important with respect to Genetics classrooms, as Genetics courses are often prerequisites and serve as the introduction to the basic genetics concepts that underlie evolution. Here, we (1) quantified the extent to which students who have taken Genetics retain and apply information to concepts in Evolution; (2) evaluated why specific fundamental concepts show differences between these courses; and (3) compared results from these courses for performance related to key genetics concepts that underlie evolution. A 16-question assessment was created from the Genetics Assessment literature (GLAI, GeDI and the Genetics Assessment For Core Understanding) and course textbooks (Mastering Genetics and Mastering Biology). Questions were multiple choice, agree/disagree, and fill-in-the-blank formats, spanned Bloom levels, and addressed documented misconceptions. Students were assessed at three timepoints: end of Genetics (to establish a knowledge baseline), beginning of Evolution (to determine what information was retained,) and end of Evolution (to determine with what information students left the course sequence). Overall and individual item performance were compared using repeated measures mixed models. We found that undergraduate students harbor many genetics misconceptions, of which only a portion may be corrected by taking Evolution. This research provides possible advantages of a Genetics-to-Evolution course sequence and a better understanding of how timing may influence the integration of material across areas of Biology.

11. Development of science identities in undergraduates underrepresented in the sciences

Amy Prunuske*, University of Minnesota; Benjamin Clarke, University of Minnesota; Hannah Marrin, University of Minnesota; Garrett Soper, ; Janelle Wilson,

The Bridges and Pathways programs are designed to encourage students from underrepresented backgrounds to pursue advanced degrees in research. These types of programs have had modest success in increasing diversity and previous analyses of these programs have been limited to a report of outcomes. To gain a better understanding of why our programs have been successful and how they might be improved, we surveyed the students using the Survey of Undergraduate Research Experiences and conducted qualitative research to gain a phenomenologic perspective on the mentors' and students' experiences. An experienced interviewer with no connections to the program conducted focus groups with the undergraduate participants. To establish credibility, a sociologist, biomedical researcher, and undergraduate independently coded the transcripts. The codes were tied to science identity theory, which argues that student persistence in science depends on their acceptance of the culture, and to codes previously identified from the mentors in the program. Students' identities in our programs were developed not only through learning to execute experiments and to read the literature, but also through professional socialization, learning how to problem solve, and improving communication skills- explicit components of the programs developed through problem-based learning and debates. Previous studies have described undergraduate research experiences as reinforcing a student's desire to pursue a research career, but for our students from underrepresented groups, it was a transformative experience giving them the confidence and connections to interact with PhDs and to continue their education. Students emphasized that a positive research experience was dependent on the mentor creating a nonthreatening environment. The insights from our analysis can contribute to diversification of the scientific workforce by developing student resilience.

12. How important are process of science skills? Student and faculty views

Elizabeth Addis*, Gonzaga University; Jo Anne Powell-Coffman, Iowa State University

The Association of American Colleges and Universities ranks multiple Process of Science (POS) skills among the top ten skills employers seek in college graduates. However, both students and faculty frequently focus on content rather than skills in class. To get students to invest in their own learning, we need to know what skills they value. Further, different skills may be emphasized by different science disciplines. To investigate these issues, we surveyed students and faculty from six different science fields on what POS skills they valued using a survey tool designed by Coil et al. (2010) that we modified. We modified this survey for students and faculty by removing all biology-specific questions and further for students by reframing the questions to ask about learning rather than teaching. Students and faculty were surveyed from the following fields: Applied biology, Biology, Chemistry, Geology, Physics, and Psychology. We found that all faculty highly valued the skills of interpreting data and problem solving/ critical thinking. Psychology also highly valued understanding statistics, but psychology and physics faculty did not value written and oral communication skills as highly as faculty from other science disciplines. Students and faculty highly valued problem solving/critical thinking and communicating results, but students more highly valued the skill of working collaboratively while faculty more highly valued the ability to interpret data. Lastly, we found a trend for faculty to feel they do not spend enough time teaching POS skills, while students are split on whether enough class time is devoted to POS skills. Faculty feel they spend more time teaching POS skills than students think they are exposed to them. Based upon the results of this study, we suggest that faculty communicate with their students why they are teaching POS skills and for faculty to increase emphasis on skills associated with working collaboratively.

13. Student Use of Procedural Knowledge in Biology

Jonathan Dees*, North Dakota State University; Caitlin Bussard, North Dakota State University; Jennifer Momsen, North Dakota State University

Conceptual knowledge refers to knowing relationships among ideas, as opposed to isolated facts, while procedural knowledge includes skills, algorithms, methods, and criteria for deciding when to apply them. Both forms of knowledge are essential for problem-solving and gaining expertise in a subject area. However, we hypothesize that biology students can successfully solve common problems in biology courses with procedural knowledge in the absence of conceptual knowledge. The present research examined two such tasks: transcription-translation exercises and Mendelian genetics problems. When required to transcribe and translate a double-stranded segment of DNA into mRNA and amino acids, students from upper-division cell biology (n=92) and biochemistry (n=195) courses generally completed the task correctly (81%). In response to a definition prompt that accompanied the task, however, only 39% of students defined "gene" as having anything to do with amino acids, polypeptides, or proteins. Similarly, when asked to answer a basic genetics question involving a single, completely dominant trait, students largely produced correct Punnett squares (93%) and correct answers (72%). However, only 43% of students defined "allele" as a variation of a gene, despite the essential role of alleles in genetics. These results suggest students can use procedural knowledge to complete problems that universally appear in biology curricula, while lacking knowledge of even the most basic concepts behind the exercises. Upon expansion to additional biology courses at different levels and additional institutions, results from this study have far-reaching implications for instruction and assessment.

15. Using Classroom Observation Data to Design Faculty Professional Development

Michelle Smith*, University of Maine; MacKenzie Stetzer, University of Maine; Erin Vinson, University of Maine

Because of the national call-to-action to transform undergraduate STEM instruction, there is increasing interest in collecting information on the range and frequency of teaching practices at department-wide and institution-wide scales. To help facilitate this process at the University of Maine, local middle and high school teachers have been observing STEM courses and collecting data using the Classroom Observation Protocol for Undergraduate STEM or COPUS. This protocol documents how instructors and students spend their time in the classroom. To date, the teachers have observed over 50 courses in 12 STEM departments attended by over 4000 students, including several biology classes. By examining how often certain behaviors on the COPUS protocol are documented (e.g., the percentage of time students spend listening, discussing clicker questions, and answering questions), we have identified three areas in which University of Maine faculty could benefit most from additional professional development. These areas include: moving from a lecture-based to a student-centered instructional environment, posing questions so as to elicit substantive student answers, and using clicker questions in a way to promote peer discussion. Here, we will discuss how we identified these areas of greatest need and how we plan to use the observation data collected to design meaningful faculty professional development.

16. Teaching Assistants' Beliefs and Enacted Practices of Learner-Centered Instruction in STEM and Non-STEM Disciplines

Brian Rybarczyk*, UNC Chapel Hill; Warren Christian, UNC Chapel Hill

Many graduate students serve as TAs for undergraduate courses, a large proportion is international students (ITAs). The question addressed is how and to what extent ITAs, as compared to American teaching assistants (ATAs) conceive of and implement learner-centered teaching. We hypothesized that ATAs enact learner-centered teaching strategies to a greater extent as compared to ITAs. ITAs from a variety of disciplines and a comparison group of biology ATAs completed surveys to determine their conceptions of learner-centered teaching and characteristics of undergraduate student learning. Qualitative responses were coded for themes and quantitative responses were compared between the two groups. COPUS observation protocol was used to characterize enacted classroom practices. ATAs' self-reported teaching beliefs oriented significantly more toward learner-centeredness as compared to ITAs ($p=0.02$,one-wayANOVA), however, both groups did not significantly differ in their conceptions of how students learn ($p=0.357$). ITAs used significantly more lecture-based teaching in the classroom as compared to ATAs ($p=0.014, Z=2.46, U=7$ Mann Whitney U test). As an indicator of high levels of learner-centered teaching,80% of ATAs implemented more frequent peer-to-peer group work as compared to 54% of ITAs ($p=0.076, Z=-1.774, U=14$). TAs in both groups posed questions to engage students with no difference in the frequency of this activity($p=0.17, Z=1.38, U=18$). These results suggest that ITAs are more instructor-centric in both beliefs and practices. ITAs implemented some learner-centered strategies but not to the extent of ATAs. Although many TA-training programs emphasize learner-centered pedagogical approaches, TAs may not always enact these strategies in the classroom. Additional opportunities for TAs to practice learner-centered teaching in STEM and non-STEM disciplines should be integrated into TA training programs.

17. Instructor assumptions about student perceptions: Are they accurate?
Cassie Dresser*, University of Tennessee; Joel Corush, University of Tennessee; Cedric Landerer, University of Tennessee

One aspect of improving student learning requires instructors to correctly interpret student perceptions and subsequently make adjustments based on those interpretations. The main objective of this study was to determine if instructor assumptions of student perceptions match the true perceptions of students. Simultaneously, we developed a computer program that anonymously pairs instructor and student surveys and automatically compares responses. For this preliminary study we issued surveys with questions pertaining to course content and instructor performance to students in four introductory biology labs. The graduate teaching assistants (GTAs) for these labs were then instructed to fill out a survey for each student predicting the perceptions of each. The GTA surveys were then compared with the survey responses of their students. Preliminary results reveal substantial variation among the four labs and across survey questions. Often, instructor assumptions were not significantly correlated with student perceptions, suggesting that GTAs may not be able to accurately predict student perceptions. For a survey question on the adequacy of evaluation methods, the assumptions made by one GTA were exactly the opposite of their students' perceptions. Alternatively, for a survey question concerning student engagement, all GTAs' assumptions correctly matched student perceptions. We feel studies such as these could increase awareness of inaccurate assumptions made by instructors regarding student perceptions and help instructors to better "read" their classrooms. In the future, we would like to expand this study to include multiple introductory biology labs from many universities to determine if there are general patterns regarding instructor assumptions and student perceptions. We believe our computer program can be widely used by SABER participants to issue surveys and improve instruction.

18. Can teaching nonadaptive mechanisms of evolution improve understanding of natural selection? Lessons learned from developing concept inventories about evolution

Rebecca Price*, University of Washington Bothe; Kathryn Perez, University of Wisconsin La Crosse

Teaching evolution effectively continues to be a challenge. Until recently, researchers have concentrated on improving students' conceptions of natural selection, but nonadaptive processes are essential components for a complete understanding of the complex richness of evolution. We introduce three new concept inventories that can be used to assess how students understand nonadaptive mechanism of evolution: the EvoDevoCI for evo-devo; the GeDI for genetic drift; and the DCI for dominance relationships in allelic pairs. The process of validating the results of these instruments led us to discover that college students' conceptions of natural selection interfered with their understanding of nonadaptive evolution. Instead of distinguishing among mechanisms of evolution, students reduce its complexity to an oversimplification: all evolution is natural selection. Therefore, misconceptions about natural selection become barriers to understanding other evolutionary processes. To further understand these barriers, we analyzed items in the inventories with distractors that included misconceptions about natural selection. We tested the hypothesis that high-performing students apply these misconceptions to explain other, nonadaptive evolutionary processes less frequently than low-performing students. We found the expected results for items in the GeDI and DCI. However, the results for evo-devo are unexpected because all students performed equally poorly. This result may be due to the fact that students encounter genetic drift and dominance relationships repeatedly in a curriculum, but are only exposed to evo-devo occasionally in isolated, advanced courses. Because many of the challenges that students have with natural selection are actually challenges about evolution—a complex phenomenon with multiple causes—we hypothesize understanding of evolution can be drastically improved by teaching more than natural selection.

19. Flipped, backwards, and upside down: challenges, opportunities, and student perceptions of an innovative first year undergraduate biology curriculum.

Kelsey Metzger*, Univ. of Minnesota Rochester

The University of Minnesota Rochester, established in 2009, is the fifth coordinate campus of the University of Minnesota system. A multidisciplinary department, the Center for Learning Innovation, offers an integrated Bachelor of Science in Health Sciences degree. Life sciences courses in the BSHS utilize many pedagogical innovations including backward course design, a flipped classroom engagement approach, deploying multiple instructors in the learning space simultaneously, and active, collaborative instructional techniques. Tenure-track faculty are involved in practitioner research that seeks to assess the efficacy and impact of these pedagogical elements by examining student performance, faculty practices in the learning space, and student perceptions of the learning space and course design. Both quantitative and qualitative approaches are used to investigate questions such as: What do students perceive as the most valuable outcomes from courses utilizing innovative pedagogical approaches? How do students respond to active and collaborative teaching practices? Are student study habits changed as a result of a flipped classroom approach? If student study habits change as a results of flipped classroom approach, in what ways and why do they change? In what ways can team teaching models be successfully utilized when multiple instructors are in the learning space simultaneously? Data from across multiple years suggests that while first year biology students "buy in" to collaborative instructional techniques and classroom engagement strategies that allow them to benefit from peer engagement, discussion, and instruction, students are less convinced about the value and efficacy of a flipped classroom course model. However, self-reported student study habits do change as a result of the flipped classroom model, resulting in study habits that advance students as self-directed learners and that students perceive to be valuable.

20. BioCore Guide: A tool to interpret the core concepts of Vision and Change for general biology majors

Sara Brownell*, Arizona State University; Scott Freeman, University of Washington; Mary Pat Wenderoth, University of Washington; Alison Crowe, University of Washington

Biology as a discipline has expanded dramatically. As we begin to acknowledge that we cannot possibly teach everything in an undergraduate biology curriculum, we struggle to come to consensus about what is most important to teach. The report Vision and Change in Undergraduate Biology Education offers a set of five core concepts that are intended to provide structure for an undergraduate biology education: (1) evolution, (2) structure and function, (3) information flow, exchange, and storage, (4) pathways and transformations of energy and matter, and (5) systems. We have taken these general concepts and interpreted what they mean for the three major sub-disciplines of biology: molecular/cellular biology, physiology, and ecology/evolution. Using a grassroots approach of soliciting input from faculty at a diverse range of institutions nationally, we have incorporated the feedback of 244 faculty members to create a set of general principles and specific statements that elaborate on each of the five core concepts. We achieved strong agreement from this national validation; over 91% of responses were in agreement with the scientific accuracy of the statements and over 93% of the responses were in agreement with the relevance of the statements for a general biology curriculum. Biology departments can use the BioCore Guide as a resource to guide curricular design, including helping faculty to articulate learning objectives aligned with Vision and Change, developing a more cohesive undergraduate biology curriculum, and identifying current gaps in the curriculum. We propose that the BioCore Guide could be used as a tool for biology departments to better align their teaching with the goals of Vision and Change.

21. Bottlenecked Ferrets: Can students learn genetic drift using a simulation-based lab?

Susan Maruca*, SimBio; Denise Pope, SimBio; Jody Clarke-Midura, MIT; Eli Meir, SimBio; Jon Herron, University of Washington

Many important concepts in evolution, such as genetic drift, are challenging to explore in a typical 3-hour lab period, but simulations allow students to visualize and investigate longer-term evolutionary processes. SimBio's simulation-based virtual lab "Genetic Drift and Bottlenecked Ferrets" features the case study of black-footed ferrets to help students understand why drift is important to threatened species and how biologists account for its effects. Students use individual-based models to discover and explore patterns around random events (mating, survival, etc.) and changing allele frequencies. In the culminating exercise, students design and test a conservation plan for endangered ferrets that minimizes the risk of loss of genetic diversity. We hypothesize that, because the lab is highly interactive, carefully scaffolded, and builds to an open-ended finale, students will be engaged and demonstrate measurable gains in their understanding of genetic drift. This lab was used by more than 30 schools in early 2014, spanning introductory and upper-level undergraduate courses. We used the genetic drift concept inventory developed by the NESCent Working Group on EvoCIs as pre- and post-lab assessments to measure learning gains achieved by students using the lab. We present data on the effectiveness of the lab at teaching concepts around genetic drift, and we make specific recommendations for future development and use.

22. Reconsidering the Non-Majors Laboratory Experience: An Examination of the Impact of Traditional Laboratory Coursework and Students' Expectations for Laboratory Learning on Student Outcomes

Jeffrey Olimpo*, Univ. of Northern Colorado; Lacy Cleveland, University of Northern Colorado

Laboratory experiences are often a standard component of science curricula nationwide, with general coursework in the biological sciences being no exception. Although significant research has been conducted exploring the impact of laboratory experiences on student learning, recent reports in the literature have reemphasized the need to structure these experiences in an authentic manner so as to improve students' scientific experimentation skills and proficiency at "doing" science. Many of these reports, however, have focused exclusively on introductory majors courses, and few explore students' expectations for laboratory learning prior to their participation in either traditional or authentic laboratory experiences. To begin to address these needs, we utilized a mixed methods approach to examine: a) non-majors students' expectations for learning in laboratory settings; b) the impact of participation in a traditional laboratory experience on students' beliefs about learning in biology; and c) the impact of participation in a traditional laboratory experience on students' academic success. Preliminary survey and interview data have shown that students' expectations center less on content-related concerns and moreso on contextual issues such as the cooperative aspects of doing science and the degree to which the laboratory exercises demonstrate real-world scientific applications. Though these data suggest that non-majors students have high expectations for practicing authentic science, further analysis of CLASS-Bio and student performance measures indicate that the laboratory experience, as it currently exists, does not have a significant impact on changing students' attitudes about learning in biology or on their understanding of related course content on summative exams. Taken together, the above findings reaffirm the need for closer evaluation of the role and structure of laboratory coursework in promoting student learning in non-majors biology classes.

23. A multi-measure assessment of course type efficacy between traditional lecture and online instruction General Biology I at a large public Hispanic-serving university.

Seth Manthey*, Florida International Universi; Eric Brewe, Florida International University; Eric von Wettberg, Florida International University; Marcy Lowenstein, Florida International University; Sat Gavassa Becerra, Florida International University; George O'Brien, Florida International University; Adrienne Traxler, Florida International University

We present the results of our analysis of the efficacy of online instruction in an introductory biology course in comparison to a face-to-face format at a large public Hispanic-serving university as we work towards reforming these courses. We have collected pre-reform data from the first semester of the introductory biology two-semester sequence. General Biology I is taught in two different formats: one lecture section is taught entirely online with a face-to-face laboratory component, and the other section is taught as a web-assisted (Blackboard) traditional lecture format with the same face-to-face laboratory setting. In order to evaluate the effectiveness of the course we follow the What Works Clearinghouse Guidelines. As part of this, we have collected multiple measures on aspects that are connected with successful curricula and are important for reform – conceptual understanding, attitudes towards and about science, course retention, and student community building. The conceptual understanding and attitudes towards science data were collected using the Biological Concepts Inventory (BCI) and the Maryland Biology Expectation Survey (MBEX) as pre- and post- course assessments. We analyze these data by course type and also disaggregating by gender and ethnicity. Course retention data were collected by beginning and end of the semester enrollment and analyzed for students earning a C or better (the minimum required to move on to the second semester), or who have dropped, failed, or withdrawn from the course. This analysis of DFW and earned grades provides us a measure of course retention. Student community data were collected through pre-, mid-, and post- course surveys and analyzed using Social Network Analysis, specifically looking for the formation of student-student collaborative networks. These results provide baseline data of the state of this course.

24. Addressing the confidence gap: Using metacognitive practices to help students to develop as self-regulated learners

Kelsey Metzger*, Univ. of Minnesota Rochester

It has been anecdotally and empirically reported in teaching and learning literature that lower performing learners are less able to accurately gauge their level of understanding than are higher performing learners, which leads to overconfidence. This so-named "Dunning-Kruger effect" also predicts that more competent learners will tend to underestimate their ability and performance, resulting in underconfidence. The present research study seeks to investigate if curriculum design incorporating regular metacognitive exercises can assist students to become better at accurately estimating their proficiency. The first year biology course at the University of Minnesota Rochester is taught in active learning spaces and implements a flipped classroom model: students are expected to complete pre-class readings and preparation in which they respond to 4-5 targeted questions about the material provided by the instructor. At the beginning of class, students engage in a low-stakes Daily Check quiz about the pre-class readings. Quizzes are taken first individually, and then repeated in collaboration with other students. The remainder of class time is devoted to a variety active learning and classroom assessment techniques. In this course, students were asked to engage in metacognitive practices at regular intervals following summative assessment (i.e. exams). Students were asked to estimate their performance on the assessment just completed, and to reflect upon their approaches to learning and studying both within and outside of the classroom space. Student estimates of performance were compared with actual performance to establish the existence of the Dunning-Kruger effect. To assess the potential impact of engaging in metacognitive practices, the gap between students' actual performance and self-reported estimated performance were compared across the semester and between high- and low-performing students.

25. Experimental analysis of active learning strategies: Why does active learning work, and how to can we use this information to guide classroom design?

Benjamin Wiggins*, University of Washington; Alison Crowe, University of Washington; Dan Grunspan, University of Washington; Sarah Eddy, University of Washington; Leah Wener-Fligner, University of Washington

Active learning is a crucial aspect of modern, equitable and ambitious STEM learning environments. What aspects of active learning are most important for learning? What aspects of classroom design contribute most to the student experience? The answers to these questions will guide the creation of successful classrooms and modules. Active learning can be grouped into two different strategies: opportunities for students to construct and opportunities for students to interact. Current theory assumes equal value to these strategies in the best, most 'transformative' active learning classrooms (Chi, 2009). Our research applies an experimental approach to differentiation of outcomes for strategies that are either constructive or interactive. We've designed activities with key strategic differences. Multiple classes are controlled for students, topic, instructor, labs, exams and overall learning environment. The same topics are covered by an interactive or a constructive strategy. For example, protein translation was taught to one group using a jigsaw (interactive) method while the other learned via individual inquiry learning (constructive). Multiple outcomes are observed in a mixed methods regime: 1) exam scores to measure long-term retention, 2) pre-post testing to capture immediate learning gains, 3) student surveying of affective differences, and 4) student focus groups to broaden categories of analysis. Linked outcome data were analyzed using multivariate log-odds regression. Preliminary findings suggest that interactive strategies have a preferential benefit to specific ethnic groups. Focus groups indicate a special importance for 'perceived instructor effort' during active learning. We are currently replicating our experiment in the same course with different instructors. We will present these findings as well as implications for activity design and implementation.

26. Assessment of Ongoing, Personalized TA Professional Development Program

Judith Ridgway*, The Ohio State University; Isaac Ligocki, The Ohio State University; Jonathan Horn, The Ohio State Univesity; Caroline Breitenberger, The Ohio State University

Teaching Assistant (TA) professional development (PD) is vital for undergraduate science education reform and for graduate education. It leads to improved student learning and retention and encourages teaching excellence as part of faculty professional identity, which is a transformative cultural change. Our PD program (PDP) has four components that provide TAs ongoing, context-specific PD: 1) initial training for first-time TAs, 2) weekly meetings with instructional staff, 3) classroom observations by CLSE staff or veteran TAs, and 4) a PD course taken by TAs every term they teach for us. The course is designed to provide customized support for TAs to improve their teaching as they progress from novices to veterans. To assess our program, we investigated TAs' perceptions of the value added by the CLSE PDP and their faculty advisors' concerns regarding TA participation in it. TA (n=69) and faculty (n=25) participants responded to surveys, and TAs participated in 3 focus groups that represented novice, mid-career, and veteran status (n=6, 7, and 8, respectively). We aligned survey items and focus group questions to research questions, including items assessing concerns as well as others aligned to National Science Education Standards for PD. We included descriptive statistics, quantitative analysis of TA and faculty perspectives, and emergent theme identification of discursive responses in our analysis. Our findings indicate that our TA population exhibits trends of increases in perceived preparedness, confidence, and teaching quality with ongoing CLSE PDP participation; TAs and faculty have mismatched ideas regarding each other's value of teaching; communication gaps exist regarding the PD course; faculty are concerned about the amount of time the PDP takes; and TAs find ongoing PD opportunities important for their careers and for the future of undergraduate education. While our findings supported the strengths of our program, we made data-driven improvements.

27. Comparison of Service-Learning and Research Projects in an Introductory Biology Class

Amy Kulesza*, The Ohio State University; Judith Ridgway, The Ohio State University; Kelsie Bernot, North Carolina A&T State University; Elisabeth Pieterson, The Ohio State University

In response to national recommendations for scientific literacy and a well-prepared workforce, our honors introductory biology class now includes service-learning, a high impact educational practice. In our model, students interact with one of three organizations to complete both a service activity and a related learning activity. Activities are designed to support students' recognition of the correlation between class concepts and real community issues. Students create a poster documenting their experiences in the context of the scientific method, choosing metrics for analyzing the efficacy and significance of their contribution. In their poster, students identify connections between classroom biology topics and their service activity. Students present posters with ideas for future contributions to peers, faculty, and community partners at a formal symposium. To determine the success of service-learning, we compared two classes, one with service-learning and the other with a standard research activity. We investigated actual and perceived student learning gains associated with course learning outcomes, student motivation to learn biology, and student perception of the relevance of biology outside of the classroom. Data were gathered through pre/post instructional surveys, the Student Assessment of Learning Gains, student assignment and course grades, and an analysis of the courses based on faculty descriptions and content analyses of the syllabi and assessments. The pre/post-instructional survey included 3 open-response questions and the 32 items in the Colorado Learning Attitudes about Science Survey for Biology. The post-instructional survey included a question regarding student experiences with research and service-learning outside of class during the semester. Student GPA, gender and ethnicity data were used to further compare the classes. We will present ANOVA and correlation results and recommendations for future modifications of our model.

28. Investigation of Changes in Introductory Biology Students Associated with Peer-Led Team Learning

Judith Ridgway*, The Ohio State University; Sara Faust, The Ohio State University; Amy Kulesza, The Ohio State University; Jonathan Horn, The Ohio State Univesity; Matthew Misicka, The Ohio State University; Caroline Breitenberger, The Ohio State University; James Chiucchi, The Ohio State University

Peer-Led Team Learning (PLTL) is an instructional approach recognized for improvement in STEM student retention and depth of learning. Although implemented in other STEM disciplines, it is fairly new in undergraduate biology classrooms. We created a 1-credit PLTL course associated with a specific introductory biology class that focuses on evolution, ecology, and organismal biology. In addition to the lecture, laboratory, and recitation, PLTL students meet for 1.5 hours in groups of 6-8 with a student leader, who was previously successful in the introductory biology course. In meetings, or workshops, the students work through challenging problems to develop a deep understanding of the content and apply it to authentic situations. Workshop topics are aligned with and integrated into the biology course components. The peer leaders have been trained to facilitate student discussions about the workshop problems and to help students make explicit their thought processes. We investigated the usefulness of our PLTL implementation by comparing the subset of students in the introductory biology course who took PLTL to those who did not to determine if PLTL participants demonstrate higher achievement on measures of the course learning outcomes and more expert perspectives on biology and biology learning than nonparticipants. We assessed scientific literacy with pre- and post-instructional questionnaires that included the Colorado Learning Attitudes about Science Survey-Biology and administered the Student Assessment of Learning Gains to assess student perceptions of achievement of learning gains and instructional aspects of PLTL. In addition, student performance on class assessments was used as a direct measure of achievement. We used demographic data and grades in chemistry and biology courses to determine if student characteristics influence the usefulness of PLTL. We will present ANOVA and correlation results and will discuss future data-based modifications.

29. Assessment of student scientific literacy skills in non-majors science courses
Justin Shaffer*, Univ. of California, Irvine

All college students are required to enroll in science courses, including general education (non-majors) science courses for those students that are not STEM majors. At the University of California, Irvine (UCI), non-majors science and technology general education courses have specific learning outcomes that state that students are expected to be able to apply scientific knowledge, analyze data, and draw conclusions. In short, they are expected to be scientifically literate and proficient in the scientific method. However, little work has been done to rigorously assess whether students are indeed developing scientific literacy skills while enrolled in non-majors science courses at UCI. In order to address this problem and to assess whether UCI students are developing scientific literacy skills in non-majors science courses, the Test of Scientific Literacy Skills (TOSLS) was implemented in a pre- and post-test format. Approximately 2500 students in eight general education science courses taught by five instructors in three departments (Biological Sciences, Chemistry, and Earth System Sciences) were recruited to participate in this study by taking the TOSLS during the first and last weeks of the Winter 2014 quarter. Learning gains will be calculated for each student that completed both the pre- and post-test, and multiple linear regression analyses will be performed to control for student demographics including major, GPA, SAT, and number of science courses previously taken. In addition, student performance on the TOSLS will be compared by course to determine whether certain courses or instructors were better able to fulfill the non-majors course learning objectives. This will allow for the identification of best practices, which can then be exported to other courses. The results from this study will be widely applicable to all colleges and universities nationwide, especially large enrollment institutions, as well as instructors who teach non-majors science courses.

30. Characterization of Biology Education Research-Practice Gap and Factors Influencing It
Travis Lund*, Oregon Institute of Technology; Marilyne Stains, University of Nebraska Lincoln

Despite the development and demonstrated effectiveness of improved instructional strategies in biology, and the advocacy of these strategies in such sources as the AAAS Vision and Change report, the level of their adoption in college biology classrooms is unclear. As indicated by the National Research Council's Discipline-Based Education Research Report, there is a need to collect reliable baseline data on faculty instructional practices in STEM disciplines. This study addresses this critical research gap by characterizing the awareness and adoption of research-based instructional strategies (RBIS) within a biology department at a research-intensive institution. In addition, we explore factors influencing the levels of awareness and adoption, including communication channels and the departmental environment. Our study utilizes Rogers' Model of the Diffusion of Innovations, a widely-implemented theoretical framework concerned with the spread of innovations throughout a system. This framework is ideal for understanding the diffusion of RBIS among a population of STEM instructors. To alleviate the limitations of self-reported data, we collected and triangulated classroom observations, student surveys, and a validated survey characterizing faculty approaches to teaching, in addition to self-reported data on the awareness and adoption of RBIS. Classroom recordings were analyzed using two existing observation protocols, the RTOP and the COPUS. A summary and interpretation of our findings will be presented, including a comparison with similar data from chemistry and physics departments at the same institution. Implications of the biology research-practice gap and factors impacting it will be discussed. This study represents one of the first attempts at providing a comprehensive description of the instructional practices of biology faculty and, as such, will be valuable to those interested in faculty development or the dissemination of effective instructional practices.

31. Following the carbon trail: Identifying evidence of systems thinking in introductory biology Jennifer Momsen*, North Dakota State University; Sara Wyse, Bethel University; Tammy Long, Michigan State University

A primary component of biological literacy is systems thinking – the ability to identify and reason about complex biological systems. Traditional undergraduate biology instruction rarely fosters the development of systems thinking. Using Structure-Behavior-Function as our theoretical frame, we define a complex system as comprised of structures linked by behaviors to perform a function. Systems thinking, therefore, involves the ability to identify relevant system structures and behaviors and synthesize those system components to produce a given function. This research focuses on identifying evidence of systems thinking in undergraduate biology in the context of ecosystem ecology, namely carbon and energy movement. Specifically, we ask (1) what structures and behaviors do students spontaneously identify as relevant to a given ecosystem, (2) how do students organize those system components, and (3) how do students reason about the movement of carbon and energy in this ecosystem following a perturbation. Our data come from introductory biology where students generated conceptual models that compared carbon and energy movement in a given ecosystem and explained the consequences of a system perturbation. Nearly all students included plants and consumers in their ecosystem models and most identified consumption as the process moving carbon and energy from plants to consumers. Roughly half of students identified photosynthesis as the process that moves carbon and energy into plants. Most student models included decomposers and the atmosphere, but failed to correctly link decomposers to the atmosphere via consumption and cellular respiration. When predicting the consequences of a perturbation on the system, most students focused on plants and photosynthesis, exhibiting linear, single-causality reasoning. These preliminary results reinforce much of the research on systems thinking in K12 learning environments and underscore a need to more explicitly teach systems thinking.

32. Development of biology concept assessments for use at the departmental level
Brian Couch*, University of Nebraska-Lincoln; Jennifer Knight, University of Colorado - Boulder; Bill Wood, ; Sara Brownell, Arizona State University; Alison Crowe, ; Scott Freeman, ; Michelle Smith, University of Maine

The ability to objectively measure students' conceptual knowledge has become increasingly important as departments work to evaluate and improve their biology programs. This poster will report the processes and outcomes of two assessment development projects. We first developed the Molecular Biology Capstone Assessment (MBCA) to gauge upper-division student understanding of fundamental biology concepts. The MBCA utilizes a multiple true-false (T/F) format where each question consists of a narrative stem followed by four T/F statements. Questions were iteratively developed with extensive faculty and student feedback, including content validation through faculty reviews and response validation through student interviews. The final MBCA, consisting of 18 questions and 72 T/F statements, was piloted to 583 students in upper-division classes at 7 institutions. Students achieved a wide range of scores with a 66% overall average. Performance results suggest that upper-division students have incomplete understandings of many concepts within molecular biology and continue to hold several incorrect conceptions previously documented among introductory-level students. We have since embarked on a collaborative effort to develop an additional suite of assessments to monitor the extent and trajectory of student conceptual understanding. These so-called BioMAPS will utilize a question format and development process similar to the MBCA but will be suitable for administration at multiple points during the biology major. Assessment content will be closely aligned to the core concepts specified in Vision & Change and the BioCore Guide, and different assessment versions will be constructed to meet the needs of general and specialized biology programs. Data from Bio-MAPS assessments will help departments by diagnosing areas in which students continue to struggle despite instruction and by enabling targeted improvement of undergraduate biology programs.

33. Talk Matters: An Analysis of Explicit Instructor Talk in a Large Introductory Biology Course

Shannon Seidel*, San Francisco State University; Amanda Reggi, San Francisco State University; Jeffrey Schinske, De Anza College; Laura Burrus, San Francisco State University; Kimberly Tanner, San Francisco State University

The critical role of the teacher in student learning has been repeatedly demonstrated in education research. Importantly, teachers not only facilitate concept learning, but also design learning environments, which influence student motivation, resistance, and self-efficacy. Communications research on instructor immediacy has found that decreased social distance between instructors and students is correlated with increased learning. Despite the potential importance of how instructors create learning environments, little research has been conducted about what instructors say and do to create learning environments in college biology classes. We hypothesize that effective instructors talk about more than biology concepts in their classrooms. To test this, we systematically investigated Explicit Instructor Talk (EIT), which we define as language used by instructors that does not directly relate to course content. Our research addresses the following questions: In an introductory biology course, 1) What types of EIT are used? 2) When does EIT happen? 3) To what extent do co-instructors differ in their use of EIT? Using a mixed-methods approach, we generated transcripts of 30 class sessions of a semester-long, co-taught introductory biology course (n=270 students) at an urban, public university. Transcripts were analyzed using grounded theory to identify emergent categories of EIT. Five categories of EIT emerged from analysis of over 500 instances including: Establishing Classroom Culture-35%, Building Instructor/Student Relationships-31%, Explaining Pedagogical Choices-18%. All five categories were represented in over 85% of analyzed class sessions with an average of 37.2 ±14.3 instances per class session. Comparison of instructors is ongoing and will be presented. Developing a framework for analyzing EIT may yield insight into varying levels of instructor effectiveness, reveal origins of student resistance, and serve as a valuable faculty development tool.

34. EvoGrader: An Online Formative Assessment Tool for Automatically Analyzing Students' Ideas in Written Evolutionary Explanations
Minsu Ha*, Stony Brook University; Ganesa Thandavam Ponnuraj , Stony Brook University; Ross Nehm, Stony Brook University

Recent literature in science education suggests that open-response assessments reveal students' ideas more meaningfully and precisely than multiple-choice assessments. However, numerous limitations of manual scoring of written answers limit the widespread implementation of practice-based assessments, particularly in large introductory biology classrooms. Our study aimed to: (1) develop an online formative assessment tool (OFAT) for automatically and immediately revealing students' ideas in written evolutionary explanations; (2) investigate the usability of the system with faculty; and (3) test the scoring efficacy of the OFAT. Our research product is the EvoGrader Web Portal (EGWP): an on-demand, machine-learning based OFAT (www.evograder.org). The EGWP allows biology instructors to upload students' typed answers to ACORNS items. Then, the EGWP automatically analyzes the responses and provides visual graphics summarizing student reasoning patterns and also generates a downloadable file including detailed information about six scientific concepts, three naïve ideas, and overall reasoning models for each response. The EGWP (1) grades responses rapidly (< 50 seconds/item for 1000 responses), (2) utilizes sophisticated and robust scoring algorithms trained by a huge corpus (> 10,000 human-scored responses), (3) reveals not only the frequency of concepts, but represents the structure of these ideas visually, (4) includes a new, user-friendly web-design based on faculty feedback, and (5) improves the security of file handling. Our results revealed that it takes about six minutes for instructors to upload and analyze 500 written explanations, and that the scoring is robust and reliable (human-computer Pearson correlation of 0.96 ($p << 0.001$) for key concepts and 0.90 ($p << 0.001$) for naïve ideas ($n = 2000$ test cases). EGWP will be of interest to biology instructors teaching large classes who seek to emphasize scientific practices such as generating scientific explanations.

35. A Comparative Analysis of Self-Explanation and Drawing as Study Strategies for Learning Biology from Text Diane Lam*, UC Berkeley

Two study strategies for learning from text have been shown, separately, in prior research to promote deeper understanding of material: self-explanation (explaining ideas aloud to oneself) and drawing. With biology text, which often involves complex systems of interacting parts and distinct functions of those parts, self-explanation and drawing are each hypothesized to promote learning in different ways. This study examines the use of these two learning strategies, separately and in combination, and their impacts on learning about the cardiovascular system (CVS). Ninety-seven undergraduate students read 11 passages of text about the CVS and studied each passage using the strategies assigned to one of four conditions: 1) Rewrite (hand-copy each passage, verbatim); 2) Self-explain; 3) Draw; or 4) Combined (self-explain and then draw). A post-test immediately following the study session and a delayed post-test administered two weeks later were used as measures of learning and retention, respectively. Results show that the Draw group displayed the highest overall gain from pre-test to post-test, attributed mainly to gains in learning about structures and the pathways in the CVS. Analyses of participant drawings suggest that the number of structural representations and labels included in a participant's drawing was predictive of learning gains about structures and pathways. In contrast, the Self-explain group demonstrated the highest retention of all groups, attributed mainly to retention of knowledge about functions within the

CVS. Analyses of self-explanations suggest that the number of goal-oriented and elaborative utterances a participant generated was predictive of their learning gains about functions. In conjunction with analyses of effects on the Combined group, this study suggests that drawing is particularly useful for learning about structures and pathways within the CVS, whereas self-explaining is useful for learning and retaining information about functions.

37. Examination of Faculty Instructional Practices and Perceptions in the Context of Reform: Year 2

Anna Jo Auerbach*, University of Tennessee; Elisabeth Schussler, University of Tennessee

The University of Tennessee, Division of Biology, is currently in the process of implementing curriculum changes to introductory undergraduate biology courses as outlined by the Vision and Change report (2011) of the American Association for the Advancement of Science (AAAS). The new curriculum is being implemented with a focus on using active learning pedagogies. Active learning (or learner centered) pedagogies have been shown to enhance student learning in introductory biology courses. An observational study documented the use of active learning within these two courses during the 2012-2013 academic year prior to the reform. During monthly instructor observations, the types of instructional pedagogies used in the classroom were recorded (i.e. clicker questions, verbal questions, small group activities), as well as their frequency and length of occurrence. Interviews with faculty asked about their perceptions of their instruction and about their course preparation. We found variability in how different instructors use active learning, and in particular, in use of student talk. We discuss the value of baseline data and how it can be used to design a professional development program with a certain context in mind. We also compare these data with active learning data gathered during the 2013-2014 academic year, the first year of implementation with implications discussed.

38. What does the fox eat? Testing biological abstraction effects on ecosystem reasoning

Joe Dauer*, University of Nebraska-Lincoln; Stephen Thomas, Michigan State University

Undergraduate students are expected to reason about biological system dynamics when they are provided with representations with a spectrum of visual support. However, it is unclear how they use those resources to reason about dynamics or what resources work best. It is hypothesized that students who reason through abstract representations are better able to generalize ecosystem dynamics than concrete representations like drawings because they are able to concentrate on the relationships instead of the objects interacting. We tested how students (n=150) performed with direct, indirect, and cyclical reasoning in a diagram describing terrestrial and marine nitrogen cycling. Diagrams were either representational drawings with words (e.g., fox, soil N, etc.), boxes containing the words, or symbols without words (e.g., $, #, etc.). Assessment items asked students to interpret the impacts of changes in model components like fox and marine fish on various other components in the model. Students reasoning with drawings and boxes performed similarly while students reasoning with symbols performed differently on each of 10 questions. Most students (>93%) reasoning with drawings and boxes were able to correctly deduce direct and indirect effects of a change in organismal abundance compared to 65%-82% correct for students reasoning with symbols. Students receiving the symbols outperformed the drawing and boxes treatments in describing both positive and negative relationships for soil nitrogen effects on plant diversity. Students reasoning with symbols may have struggled to reason about multiple components as they recorded fewer components on nearly every question. While reasoning with abstractions may be desirable, the cognitive load associated with abstract tasks may reduce the amount of reasoning possible. How instructors scaffold ecosystem reasoning may be critical to allowing students to reason through abstract representations later in their biology careers.

39. Gendered Experiences: Illuminating Hidden Inequities in Introductory Biology

Sarah Eddy*, University of Washington; Dan Grunspan, University of Washington; Sara Brownell, Arizona State University; Benjamin Wiggins, University of Washington

Although gender gaps are a major concern in male dominated STEM disciplines, the numerical dominance of females in biology is seen as evidence for gender equality in the life sciences. However, this surface measure could be masking nuanced gender inequalities. To test for these, we combine multiple lines of evidence across several large introductory biology classes at one R1 university. In doing so, we create a holistic picture of the experiences of students in these classes. We collected data on self-reported confidence with classroom content, participation patterns in large and small groups, students' perception of their peers' content knowledge, and student achievement. We analyzed these data using rigorous statistical approaches including longitudinal social network analysis, mixed effect modeling, and Poisson and ordinal regressions. Gender matters across all measures. Females were at least two times more likely than males to report (a) less confidence in their content knowledge and (b) more anxiety about small and large group participation. Classroom observations reveal that females participate less in class: answering only 37% of instructor-posed questions, despite constituting 59% of the classroom population. When asked to name peers who are knowledgeable in the class, students in the first week of the term name males and females equally, but a significant bias towards males emerges as the class progresses. Finally, we find a small but significant achievement gap between male and female students in exam scores (2.6%). Based on our results we propose a model of how self-perception influences classroom participation and ultimately how students are perceived by their peers. Our model suggests how classroom dynamics can lead to the perpetuation of gender gaps in perceived science ability and potentially the persistence of females in the sciences. Based on our model we offer strategies that instructors can implement to partially mitigate these effects.

40. A Comparison of Self-explaining and Drawing as Strategies for Learning from Text

Kristina Yim*, UC Berkeley; Michael DeChenne, ; Diane Lam, UC Berkeley

Self-explanation and drawing are closely aligned strategies for learning—both are constructive activities that engage students in active learning, and both have been shown to help learners develop a deeper understanding of material. In this study, we compare the effects of these strategies on learning from text and attempt to identify aspects (both positive and negative) that are unique to each. 97 undergraduate students participated in independent study sessions during which they were asked to read ten passages of text about the cardiovascular system and 1) rewrite, 2) self-explain, 3) draw a figure for, or 4) self-explain and then draw a figure for each passage as they read. Preliminary analyses of written assessments given prior to, immediately following and two weeks after the study sessions revealed significant differences between students in the self-explanation group and students in the drawing group, in terms of overall gains and retention as well as for specific types of understanding. Our findings suggest that drawing may have the most benefit for learning, with an emphasis on structures and pathways, while self-explanation may have the least. This is supported by an analysis of post-test drawings—when asked to draw structures and pathways of the cardiovascular system,

students in the drawing group included the most correct elements while students who only self-explained included the least. However, the opposite may be true for retention. After two weeks, the self-explanation group retained the most of what they had learned, with an emphasis on functions, while the drawing group retained the least.

41. Connections between student explanations and arguments from evidence about plant growth

Jenny Dauer*, University of Nebraska-Lincoln; Jennifer Doherty, Michigan State University; Allison Freed, Michigan State University; C.W. (Andy) Anderson, Michigan State University

In this paper we focus on how students connect explanations and arguments from evidence about plant growth and metabolism—two key practices described by the Next Generation Science Standards. This study reports analyses of interviews with 22 middle and high school students post-instruction, focusing on how their sense-making strategies lead them to interpret—or misinterpret—scientific explanations and arguments from evidence. The principles of conservation of matter and energy provide a framework for making sense of phenomena, but our results show that students often reason about plant growth as an action enabled by water, air, sunlight, and soil rather than a process of matter and energy transformation. Many of these students re-interpret the hypotheses and results of standard investigations of plant growth such as von Helmont's experiment to match their own understanding of how plants grow. We also observed that students often improved their explanations and arguments when provided with scaffolds during the interview. We use these analyses to show how student beliefs and habits of mind can lead to alternate interpretations of both arguments from evidence and instructional explanations. We describe our progress and challenges developing teaching materials with scaffolding to improve students' understanding of plant growth and metabolism.

42. A Comparative Examination of Student and Faculty Expectations for Learning in an Inquiry-Based Advanced Cellular and Molecular Biology Laboratory Course

Jeffrey Olimpo*, Univ. of Northern Colorado; Biscah Munyaka, Univ. of Northern Colorado; Sue Ellen DeChenne, Univ. of Northern Colorado

Recent reports in the literature comparing undergraduate students' performance and attitudes about learning in traditional versus authentic biology laboratory contexts have suggested that engaging students in doing "real-world" science leads both to enhanced mastery of course content, as well as a deeper appreciation for, and interest in, scientific research. While informative, many of these studies have focused only on students' participation in inquiry-oriented experiences at the introductory level or with a self-selected sample, and few, if any, have examined student and faculty expectations for learning in authentic laboratory environments. To address this need, we are currently conducting a qualitative study aimed at generating a comparative account of student and faculty expectations for learning in an upper-division cellular and molecular biology laboratory course focused on developing students' scientific experimentation and process skills. Preliminary descriptive interpretive analysis of end-of-course interview data suggests that although faculty remained in alignment regarding course objectives, structuring of the authentic laboratory experience, and assessment techniques, students claim that they "did not learn anything" because the course "had no organization" despite their initial expectations that they would be doing "science the way it's practiced in the field." Interestingly, data suggest also that affective measures, such as students' attitudes about the course instructor, may play an integral role in how students ultimately perceive and engage in these authentic experiences, with less favorable views of the instructor correlated with lower engagement in the course. Together, these data highlight the importance of attending to both student and faculty views of learning in inquiry-based laboratory environments in an effort to better structure these environments to promote student learning.

43. NextGen CURE Assessment

Lisa Auchincloss*, University of Georgia; Aspen Robinson, University of Georgia; Sarag Merkel, University of Georgia; Erin Dolan, University of Georgia

Vision and Change champions the involvement of all undergraduate biology learners in doing science research. Course-based Undergraduate Research Experiences (CUREs) can help accomplishing this by involving all students enrolled in a course in addressing a research question. Most CURE assessment has been limited to descriptive accounts as well as student reports of outcomes, such as their gains in science knowledge and skills. However, CUREs vary in their duration, timing, focus, intent, and planned activities. This variation is likely to affect student outcomes. In addition, what makes CUREs distinctive from other learning experiences has not been clearly defined. A recent report based on feedback from an expert panel and a thorough review of the literature (Corwin Auchincloss et al., 2014) proposes that CUREs comprise five dimensions, specifically, they: (1) involve students in scientific processes, (2) provide students the opportunity to make discoveries, (3) involve students in work that has the potential for impact outside the classroom, (4) involve students in collaborative work, (5) and involve students in iterative processes. We have designed a survey aimed at measuring these hypothesized dimensions. Ultimately, we hope this survey will be useful for: (A) determining if a learning experience is a CURE, (B) distinguishing CUREs from other lab learning experiences, such as labs that are taught using traditional instruction, and (C) characterizing the extent to which CUREs vary. We will present data from a pilot study aimed at determining the validity and reliability of the survey as a measure of the five dimensions and of CURE instruction in general. During the 2014/2015 school year, we will be collecting data from instructors who teach labs using a variety of approaches as well as their students, with the aim of distinguishing between CUREs and other forms of lab instruction.

44. Creating a Culture of Engaged STEM Learners: Implementing Evidence-Based Interventions to Improve Learning and Transfer in Diverse Classrooms

Clark Coffman*, Iowa State University; Patrick Armstrong, Iowa State University; Catherine Brewer, New Mexico State University; Shana Carpenter, Iowa State University; Jennifer Curtiss, New Mexico State University; Jessica Houston, New Mexico State University; Monica Lamm, Iowa State University; Robert Reason, Iowa State University; Michèle Shuster, New Mexico State University

Equipping students with the skills required to engage in and monitor their own learning is key to their success. However, evidence-based student-centered instructional strategies frequently do not align with student expectations of what learning should look and feel like. The most effective learning strategies are often not used by students because they require more effort and put learners in situations where they may make initial mistakes. These factors give students the perception that they are not "being taught" by their instructor. The goal of this project is to design, implement, and optimize instructional interventions that improve student success and metacognitive awareness. We are testing the hypothesis that allowing students to experience a variety of learning strategies and then showing them the outcomes of using these strategies will improve their metacognitive abilities and lead to choices of more effective learning approaches. In this study we: (1) develop interventions that are based on empirically-validated techniques known to enhance learning, (2) allow the students to experience learning using these interventions, showing them the data associated with their experiences, and (3) measure the effectiveness of these interventions as a function of individual student characteristics that are often overlooked--namely, prior content knowledge, learning achievement goals, motivation, and readiness for change. The ultimate goal of this project is to develop a data-driven intervention and assessment system that enhances students' understanding and application of course material, and encourages individual reflection on effective learning. We will present recently collected baseline data from a 370-student introductory biology course. In this preliminary study, we implemented one intervention (retrieval practice), included pre- and post-tests to monitor learning gains, and piloted a survey instrument to measure study preferences, learning goals and attitudes.

45. A National Survey of Biology GTA Professional Development: Preliminary Recommendations for Best Practices

Elisabeth Schussler*, University of Tennessee; Quentin Read, University of Tennessee, Knoxville; Miriam Ferzli, North Carolina State University; Rosa Hainaj, Lorain County Community College; Denise Kendall, University of Kentucky; Julie Luft, University of Georgia; Gili Marbach-Ad, University of Maryland; Kristen Miller, University of Georgia; Susan Musante, American Institute of Biological Sciences; Kimberly Tanner, San Francisco State University; William Wischusen, Louisiana State University

For biology graduate students serving as graduate teaching assistants (GTAs), scientific training sometimes precludes the development of teaching skills. Given that GTAs often teach important components of introductory majors' courses, improving gateway courses must include GTAs. The Biology Teaching Assistant Project (BioTAP) is an NSF-funded research coordination network to connect people and resources to improve GTA teaching. A steering committee compared GTA professional development (PD) practices across several institutions, but discovered little consensus. The group therefore undertook a national survey to answer two questions: 1) Can best practices be identified by a wider institutional survey? and 2) What resources do institutions need to improve GTA PD? The survey was sent to professional organizations (i.e., SABER) and individuals with GTA training responsibility at research institutions across the US and Canada; 91 individuals at 81 institutions responded. Many (40%) institutions devoted < 10 hours per year to GTA PD. However, time was not correlated with self-reported training effectiveness, suggesting that program coordinators focus more on program content than length. Pre-semester orientations were the most common PD offering; semester offerings were rare or optional. Over 30% of programs had mandatory teaching observations, 18% had mandatory peer mentoring programs, and 10% required faculty mentors. The most common suggestions for program improvement were dedicated courses, mandatory participation in training, formal teaching feedback (including common assessments), and increased support from faculty and staff (although 59% rated institutional support average or better). Programs who self-reported the highest satisfaction with GTAs cited their formal mentoring and pedagogy courses. We suggest institutions create formal semester-long GTA pedagogy courses, but in their absence, increase structured mentoring opportunities to supplement formal training.

46. Instructional cues and modeling positively impact small group discussions.

Sarah Wise*, University of Colorado; Erin Furtak, University of Colorado; Jennifer Knight, University of Colorado - Boulder

Discussions of clicker questions and other in-class activities are known to improve learning, but little is known about student behaviors during such discussions, or how instructional techniques may influence them. In this quasi-experimental study, small group discussions of clicker questions in two matched sections of introductory biology were audio-recorded and transcribed. One section received instructional guidance to articulate reasons during discussion (treatment), while the other was only prompted to engage in discussion (baseline). The sections were taught by the same instructor, used identical clicker questions, and were similar in all other demographic measures. A total of 114 discussions of 12 clicker questions were transcribed. Several measures of participation were calculated for each discussion, including length and the proportion of time spent on-task. Each discussion was also coded for characteristics of argumentation: the exchange of quality reasoning, rephrasing of reasons, use of reasons for multiple answer choices, and use of analogies or examples. On average, small group discussions lasted around two minutes and were on task 53% of the time. To measure the impact of instructor cues to use reasoning, we used a regression model controlling for clicker question. Discussions in the two sections were similar for several characteristics, including student use of analogies and rephrasing of reasons. However, discussions were significantly different in student use of reasoning. Discussions from the treatment section were more likely to contain exchanges of quality reasoning, reasons for multiple answers, and hedging of reasoning than discussions in the baseline section. This study demonstrates that simple, time-efficient methods of instructional guidance positively impact student discussions. We will discuss further implications of the data and ways to apply these findings to improving discussions in the classroom.

47. Student-Student Questioning in Introductory Biology Clicker Discussions

Sarah Zimmermann, University of Colorado; Sarah Wise*, University of Colorado; Jennifer Knight, University of Colorado - Boulder

Previous studies have suggested that students learn more from whole-class discussions when teachers use questioning techniques that focus on reasoning. Building on these findings, we have characterized student-student questioning during clicker discussions, and investigated whether instructional guidance to use reasoning influenced such questioning. A total of 114 discussions of 12 clicker questions were transcribed. We chose to track four types of questions: requests for information, direct and indirect requests for reasoning, and requests for feedback. Working from the hypothesis that indirect and direct requests for reasoning or feedback might stimulate further reasoning, we placed discussions in one of four categories: those lacking questions, those only featuring requests for information, those featuring one request for reasoning or feedback, and those featuring more than one kind of request for reasoning or feedback. Overall, students most frequently made requests for information, followed by requests for feedback. In the treatment section (where instructors guided students to articulate reasoning), students were significantly more likely to request feedback and indirectly request reasoning. These discussions were also more likely to feature multiple kinds of reasoning and feedback questions, compared to the baseline section (no reasoning guidance). In addition, we found that when students asked more than one type of reasoning or feedback

question in their discussion, they spent more time overall in discussion. These findings suggest that both student-student questioning and instructional guidance to articulate reasoning impact features of discussion (see also Wise et al. and Knight et al. abstracts). We will suggest additional ways to encourage student-student questioning in order to stimulate meaningful discussion of active learning exercises.

48. Storyboarding for genetics assessments: Alternatives for NGSS

Michele Korb*, Cal State Univ. East Bay; Shannon Colton, MSOE; Gina Vogt, MSOE

Biology courses often challenge students with complex interconnected ideas and unique vocabulary that may pose barriers to students' understanding of biological processes. Students are frequently asked to identify and repeat meanings of terms in written assessments. Exercises like these often result in the general inability on the students' part to situate individual concepts into a larger, relevant and scaled framework that demonstrates the relationships of the content in contextual environments. Engaging students in the process of modified storyboarding can assist in anchoring difficult terminology and processes into a bigger picture. We define "modified" storyboards as pre-printed images provided to students as visual scaffolds for anchoring science terminology versus drawing their own complex structures from scratch. Storyboarding enables students to use models in order to construct an explanation using evidence to support the hypothesis, practices emphasized in the Next Generation Science Standards (NGSS). This method has been piloted in various middle school classrooms in California and current data is being collected to demonstrate the effectiveness of using this strategy to anchor student learning. Preservice teachers currently collecting the data engage in the analysis of how storyboards impact student understanding of genetics and inform their pedagogy. This presentation will model storyboarding as an opportunity for performance assessment of students' content knowledge against a backdrop of observing patterns, determining scale, and establishing relationships between structure and function, and crosscutting concepts within the NGSS Framework. This interactive presentation emphasizes the practice of and results for an updated perspective on their use as framed by the practices and crosscutting concepts outlined in the NGSS framework as a way for educators to develop and use storyboards as a type of performance assessment.

49. Using a genetics concept inventories to inform pedagogy for middle school students and teachers

Michele Korb*, Cal State Univ. East Bay; Dianne Anderson, Point Loma University of the Nazarene; Eric Hagedorn, University of Texas-El Paso; Matt Silberglitt, WestEd- Oakland, CA; Megan Jensen, CSU - East Bay

The American Association for the Advancement of Science (AAAS) urges an increase in biomolecular literacy among middle school learners. Research provided by the AAAS indicates that fewer than 25% of middle school students have an understanding of molecular interactions in living systems. The understanding of the functioning of cells, proteins and the molecular basis of heredity are important topics for middle school students to grasp to prepare them for high school (Lempinen, 2010). Few studies have been conducted of student misconceptions, knowledge frameworks and prior knowledge at the middle school level in the biological sciences. In order to assess learning in the sciences, the use of concept inventories have been crucial in the areas of physics and engineering to impact change in teacher pedagogy. The tool provided in this presentation (the Life Science Concept Inventory- LSCI) is a criterion-referenced tools aimed at monitoring changes in student content learning, cognitive capacity related to science reasoning and informing positive changes for the ways in which educators teach science. Those developed for the life sciences (Anderson et al, 2002; Klymkowsky, et al, 2003, Smith, et al, 2008) assume college level literacy, (the Conceptual Inventory of Natural Selection has recently been revised for middle school and is currently being field-tested (Anderson, 2013)). There are few studies of student misconceptions and alternative conceptions at the middle school level in the biological sciences, specifically in genetics and molecular biology. The goal of this presentation is to present the data from 6 years of development, statistical analysis and practical use of the LSCI. Data analyses reveal specific trends in common misconceptions middle school students hold regarding genetics and interesting interpretations of what they understand to be correct. The results have implications for adjustments to middle school teacher pedagogy in the life sciences.

50. What kinds of people do science? Scientist Spotlights as an intervention for addressing science identity in an introductory biology class.

Jeffrey Schinske*, De Anza College; Jahana Kaliangara, De Anza College; Monica Cardenas, De Anza College

Gee (2000) defines identity as recognition of oneself as a certain “kind of person.” For many reasons, college students may find their identities in conflict with their perceptions of a scientific identity. Indeed, students’ choice not to adopt a science identity partially accounts for low retention in the sciences. However, little research has measured students’ science identities or developed interventions to enhance such identities. We studied biology students’ perceptions of the “kinds of people” who do science and evaluated a related intervention. We hypothesized: 1. students would initially possess stereotypical views of people who do science 2. an intervention using Scientist Spotlights would help students identify with prominent scientists and 3. science identity-related gains would be especially strong for traditionally underrepresented students. We conducted this study in an introductory biology class at a highly diverse community college. On the second and last days, students completed constructed-response assessments of science identity. Students also completed weekly assignments called Scientist Spotlights that introduced course topics through specific scientists. Scientists were selected for content relevance and for diverse backgrounds (ethnicities, ages, genders, socioeconomic statuses, etc.). Students wrote reflective essays on what they learned, including what they discerned about the types of people that do science. Pre/post responses were blind-coded into three categories: 1. common stereotypes 2. diversity-oriented descriptions and 3. neutral descriptions. Statistical analyses of the number of comments per student from each category showed significant pre/post class differences, allowing rejection of null hypotheses. Overall, students shifted toward more-nuanced diversity-oriented language to describe scientists. By the end, the vast majority (76%) of students felt they knew of one or more scientist with whom they could personally relate.

51. Gender Bias in Lesson Models for Biology Education

Amy Buxton*, Brigham Young University; Jamie Jensen, Brigham Young University

While extensive research has been conducted examining gender stereotypes and the gender gap within education, past research has not focused on how to improve student interest and learning within biology by the specific lesson models teachers employ (“models” being the specific lesson content used to teach a broader biology concept, e.g. bird plumage is a model to teach sexual selection). We have developed an instrument to measure if, when, and what lesson models exhibit gender bias in biology. We selected eight broad topics within biology, and created three sets of flashcards within each topic. Within each set, one flashcard depicts a stereotypically male model (e.g. a shark) that could be used to teach the topic, while the other depicts a stereotypically female model (e.g. a dolphin). We gave this survey to 25 male and 25 female students in each grade, k-6, as a way of collecting preliminary data. We found several models that display significant gender bias. Our long-term goal is to create curricular materials based upon these biased models to test if they affect male and female interest and learning in biology.

52. Perceptions and influences behind teaching practices in STEM classes: Do "teachers teach the way they were taught"?
Stephanie Cox*, Brigham Young University; Jamie Jensen, Brigham Young University

Schools face the problem of STEM retention. Many put the blame on the way teachers are educated, which is often not student-centered, citing that "teachers teach the way they were taught," current education is also not student-centered. The idea that "teachers teach the way they were taught" is commonly used to promote an agenda and accepted as fact in scientific literature. However, little empirical data has been collected to support this conclusion. We aimed first to determine empirically if teachers teach the way they were taught, and second to determine the influences behind teaching practices. We observed, surveyed, and interviewed a sample of 44 instructors at seven colleges and universities throughout the state of Utah who taught select STEM introductory courses. Instruments used included observational, survey, and interview protocols developed specifically for this study during preliminary trials. A paired t-test was used to compare the professor's teaching practices with their own educational experiences. Interview responses were then used to determine the influences behind teaching practices. In our analysis, we discovered that there is a significant difference between how teachers teach and their own educational experience. This finding rejects our hypothesis that teachers teach the way there were taught. Qualitative data from interviews introduces a new hypothesis that teachers teach the way they themselves preferred to be taught, or the way they think students learn best. Our results reinforce the importance of exposing future teachers to current, evidence-based pedagogy in classes because they will teach the way they were taught if it is a positive experience. For those higher education teachers already teaching, reform efforts will only be effective if the teachers' own internal philosophy is changed through enlightened mentors or peers, exposure to research, and/or theory-based education classes.

53. Investigating the Impact of Faculty Learning Communities on Biology Instructors
Jill Voreis*, University of Georgia; Tessa Andrews, University of Georgia; Meghan Federer, Ohio State University; Jennifer Knight, University of Colorado - Boulder; John Merrill, Michigan State University; Ross Nehm, Stony Brook University; Luanna Prevost, University of South Florida; Michelle Smith, University of Maine; Mark Urban-Lurain, Michigan State University; Paula Lemons, University of Georgia

Although faculty learning communities (FLCs) have the potential to facilitate changes in the teaching strategies of STEM instructors, few researchers have investigated the impact of FLCs on instructors. We are conducting a five-year study of nineteen FLC participants who are biologists at one of six research I universities. These FLCs were created to support implementation of the Automated Analysis of Constructed Response project (AACR, www.msu.edu/~aacr). AACR provides instructors with automated feedback on students' written responses to conceptual questions, primarily in introductory biology. This study explores the role of the FLC in the implementation of AACR. In particular, how does participation in an FLC impact instructors' conceptions of teaching and learning and their implementation of new teaching practices?

We used semi-structured interviews to investigate instructors' perceptions of their FLCs and the Approaches to Teaching Inventory (ATI) to measure instructors' conceptions of teaching and learning. We also used the Classroom Observation Protocol for Undergraduate STEM (COPUS) to document instructors' actual teaching practices in the classroom.

Thus far, instructors report their FLC experience is valuable and necessary for their adoption and sustained use of AACR. From the ATI, instructors on average (1) frequently design their teaching with the assumption that most students have very little useful knowledge of the topics to be covered, and (2) only sometimes make available opportunities for students to discuss their changing understanding of the subject. COPUS data reveal that the instructors participating in the study use a variety of instructional strategies, with some primarily lecturing, and others including more active teaching strategies such as posing and answering questions, and encouraging peer discussion. These data and additional data will be presented in detail.

54. Scientific Reasoning Skills May Contribute to Student Retention in Science, Technology, Engineering, and Mathematics Majors

Jamie Jensen*, Brigham Young University; E. Neeley, Brigham Young University; Jordan Hatch, ; Ted Piorczynski, Brigham Young University; Dane Berry, Brigham Young University

The United States is not producing enough Science, Technology, Engineering, and Mathematics (STEM) graduates to meet growing demand. The two main causes of attrition have been found to be disappointment with the curriculum and a loss of academic self-confidence in a highly competitive environment. We set forth to investigate scientific reasoning ability as a possible interacting factor in the loss of students from STEM degrees. To investigate if and when scientific reasoning may play a role in retention, we took a snap shot of introductory biology students at a large private university in the western United States. We classified students as either STEM or non-STEM majors and assessed their reasoning ability using the Lawson Classroom Test of Scientific Reasoning administered at the beginning of the course. We found that reasoning ability correlates with final course grades as well as performance on high-level final exam items. In addition, it appears that sorting, based on scientific reasoning ability, does not occur until after the freshman, or even sophomore, year. Two reasoning patterns, in particular, seem most responsible for sorting: Identifying and controlling variables and hypothetic-deductive reasoning. We suggest that this shift is likely due to negative experiences in the introductory STEM courses and suggest educational interventions that may plug the leaky pipeline in STEM education.

55. Characterizing statistics misconceptions in graduate students and postdocs in the life sciences

Abha Ahuja*, Harvard Medical School; melanie Stefan, Harvard Medical School

A basic understanding of statistics is essential for conducting biological research, but many research papers are published with clear misuse or misinterpretation of statistical analyses (Vaux 2012). It is imperative to train life scientists in proper use and interpretation of statistics, and help them frame problems in the context of examples from life sciences. Statistical

misconceptions have been described in the education research literature, and the nature of these misconceptions is well documented among varied populations (Sotos et al 2007). However, a systematic study of misconceptions among life science post-graduates has not been performed. We are developing a pre-post test to assess statistics knowledge in doctoral students and postdocs enrolled in a course titled "Fundamentals of Data Analysis for Experimental Biologists". The survey instrument contains questions about (1) student demographics, attitudes about, and confidence in, conducting statistical analyses adapted from "Assessment Resource Tools for Improving Statistical Thinking" surveys (2) statistics concepts, application, and interpretation adapted from published concept inventories. The concepts assessed fall under three categories: Confidence Intervals, Sampling Distributions and p-values. We hypothesize that certain categories will be underrepresented in researchers, while others may be overrepresented. Preliminary findings suggest that these students misunderstand the application of theoretical sampling distributions to real data. Once complete and validated the survey will be administered to post-graduates at additional research institutions to gain a broad understanding of specific types of statistics misconceptions in post-graduates. Characterization of statistics misconceptions in different student populations at different levels of training will provide insight into how conceptual change occurs in the understandings of statistics, and inform the design of courses and curricula.

56. Engineering an Educational Exam Experience

Jamie Jensen*, Brigham Young University; Tyler Kummer, Brigham Young University; Dane Berry, Brigham Young University; James Dalgleish, Brigham Young University

Previously we have shown that writing exams at higher-orders of Bloom's Taxonomy leads to improved student learning on both higher-order conceptual understanding as well as lower-order terminology over traditional recall exams. However, this added benefit comes at a cost to student satisfaction. To assess if we could reap the same benefits of higher-order exams with less student resentment, we implemented two treatments. First, we administered standard- and abbreviated-length high-level exams to two populations of non-majors biology students. Second, we administered abbreviated-length high-level exams with an additional 50 simple recall questions in order to test whether additional recall would facilitate exam performance with the added benefit of boosting student confidence and satisfaction. In both experiments, we gathered unit and final exam performance data between conditions. We show that abbreviated high-level exams led to lower performance on assessment items shared between conditions, possibly lending support to the spreading activation theory. It also led to lower performance on the final exam, lending support to the testing effect in creative problem solving. In contrast, additional low-level questions did not lead to any significant gains in performance over the standard-length on unit or final exam items, nor did it increase student satisfaction. We came to two conclusions: 1) Although shorter exams resulted in somewhat greater student affect, providing additional high-level questions increases student learning and retention of high-level conceptual understanding as well as low-level recall, and 2) The addition of terminology-based recall questions on unit exams does not facilitate student learning or attitudes. We recommend, therefore, that our focus should be placed on writing high-level assessment items only and that a reasonable number of items should be included so as to facilitate learning.

57. Presence of teleological, essentialist, and anthropocentric reasoning predicts biological misconceptions among biology and non-biology students

Kimberly Tanner*, San Francisco State University; John Coley, Northeastern University

Biology education researchers have documented persistent scientifically inaccurate ideas, often termed misconceptions, among biology students. Additionally, cognitive psychologists have described intuitive conceptual systems – teleological, essentialist, and anthropocentric thinking – that humans use to reason about biology. We have hypothesized that seemingly unrelated biological misconceptions may have common origins in these intuitive ways of knowing, termed cognitive construals. To investigate this hypothesis, we constructed 12 misconception statements, each hypothesized to be linked to a specific cognitive construal. Biology (n=69) and Non-Biology majors (n=68) at a 4-year university were asked to rate their agreement with misconception statements and to explain their reasoning in writing. Analyses were assessed: 1) students' agreement with misconception statements, 2) presence of construal-based reasoning in written responses, and 3) correlations between these metrics. Comparisons were made between Biology and Non-Biology majors with ANOVA, Chi-square, and regression analyses, where appropriate. While many statistically significant findings emerged, we share four here: 1) The vast majority of Biology (93%) and Non-Biology Majors (98%) agreed with at least one biological misconception. 2) These populations were similar in using construal-based reasoning at least once in written explanations ($p > 0.420$). 3) While more Non-Biology Majors employed essentialist and anthropocentric reasoning, more Biology Majors employed teleological reasoning. 4) Strikingly, the frequency of construal-based reasoning predicted misconception agreement more strongly among Biology than Non-Biology Majors. In summary, these data support the hypothesis that biological misconceptions may indeed have origins in intuitive ways of knowing. Moreover, they raise the intriguing possibility that university-level biology education may reify construal-based thinking and related misconceptions.

58. Knowledge-building as a theoretical framework for biology education research

Anne-Marie Hoskinson*, Michigan State University; Jessica Maher, Michigan State University; Tammy Long, Michigan State University

Recent calls for reform of K-16 science curricula (e.g. Vision & Change, PCAST, NGSS) emphasize deep concepts and practices: working with data, numeracy, modeling, and collaboration. Currently, there are few evidence-driven means of evaluating students' deep conceptual ideas; likewise, research on the value of scientific practices for students, and best strategies for teaching practices, lack unifying organization. If biology education research is to be evidence- and research-driven, then we must generate theoretical models around the nature of scientific knowledge, how it is built and disseminated, and student and instructor roles in those processes. Presently, our ideas of what constitutes scientific knowledge have grown beyond, and hence no longer align with, existing metrics' capabilities to evaluate how instructors and students create, represent, and interact around scientific knowledge. We assert that ideas about scientific knowledge, and how people interact with that knowledge, requires similar transformative thinking and efforts as are currently underway in our classrooms. Scientific knowledge building (SKB) is a framework for how people can and should interact powerfully with and around scientific knowledge, and evokes how students can develop deep conceptual understanding and disciplinary practices. Synthesizing research from behavioral and cognitive sciences, conceptual change, epistemology, social learning, and BER, we propose SKB as a theoretical model for understanding the creation and nature of scientific knowledge. The proposed theoretical framework of SKB is a set of unifying principles that: organizes existing work; can help systematize our approaches to BER; and proposes testable questions on: 1) systematic development of disciplinary practices, 2) methods for capturing and evaluating student knowledge; 3) justification for teaching and assessing concepts and practices, and 4) epistemology of scientific knowledge for all, novice to expert.

59. Student Attitudes and Beliefs about Biology: How College Student Epistemologies Can Impact Instruction in Introductory Biology Courses

Katherine Mollohan*, The Ohio State University; Lin Ding, The Ohio State University; Judith Ridgway, The Ohio State University

Students' epistemologies—their beliefs and views about knowledge and learning—have been found to affect their content knowledge. Past research in multiple scientific disciplines has revealed that undergraduates in large-enrollment introductory science courses become more novice-like in their thinking about knowledge in the field over the course of the semester. However, little research has been conducted to examine the differences between science and non-science majors in this regard. Specifically, we examined the differences between science and non-science majors in introductory courses, and their changes in epistemologies over the course of one semester of instruction. Participants were students enrolled in either major or non-major introductory biology courses (n=171). We utilized a pre-post survey methodology using the Colorado Learning Attitudes about Science Survey for biology (CLASS-Bio) and the scoring spreadsheets provided by the CLASS-Bio authors. Significance was determined by conducting t-tests. Pre-instruction results indicated that there were significant differences between the science majors and non-science majors overall and in individual categories. The science majors exhibited a higher percentage of favorable responses (responses deemed more expert) than the non-science majors ($p < .01$). Post-instruction results reversed this trend, with the non-majors outperforming the majors. Through matched comparisons we found that science majors shifted toward more novice-like epistemologies over the course of the semester whereas the non-science majors displayed positive gains (though not all of these gains were significant). The between-group differences for the post-instruction survey are significant ($p < .01$) overall and for most categories. These results force us to ask what we are doing with the non-science majors that we aren't doing with the majors to bring about epistemological gains. Implications for instruction will be discussed.

60. Teasing Apart Self-explanations: How the Types of Utterances Generated while Self-Explaining May Impact Learning from Biology Text

Norielle Adricula*, U.C. Berkeley Dept. of Educati; Alex Tseng, U.C. Berkeley Dept. of Education; Diane Lam, UC Berkeley

The self-explanation (SE) effect describes the phenomenon whereby learners who explain ideas to themselves aloud while reading are more likely to learn the material than those who do not or do so less frequently. This research utilizes linguistic analyses to go beyond investigating if self-explanation promotes learning biology from text and looks at how self-explanation promotes that learning. Fifty undergraduate students participated in 1-2 hour study sessions after one of two trainings: how to self-explain, or how to self-explain and draw. Each participant was then asked to utilize the strategies for each of the 11 passages of text about the cardiovascular system (CVS). A detailed coding scheme was developed to distinguish types of utterances that these students generated while studying. The relationship between the frequency of these different utterance types and performance on free-response assessment questions was examined. The questions were designed to measure three different types of understanding of the CVS: structures within the system, pathways that blood flows through, and functions of composite parts. Preliminary statistical regression analyses revealed that utterances of a goal-driven or elaborative nature were statistically significant predictors of learning about functions in the CVS. Results of this study suggest different strategies for how students might enhance their learning from text; namely, students should think about the goals of components within a system as well as elaborate on details beyond what is made explicit in the text. These findings inspire further analyses into the types of explanations that students may generate while learning text in order to improve learning and understanding of biology material.

61. Using the Knowledge in Pieces framework to address recurring challenges in representational competence

Matthew Lira*, University of Illinois at Chi

Contemporary reform efforts in biology education aim to integrate other STEM disciplines into the biology curriculum. Consequently, research in biology education would benefit from parsimonious, theoretical models that align with models of learning from other STEM disciplines. The Knowledge in Pieces (KiP) framework offers a robust and generative cognitive model of the conceptual dynamics that STEM students display when thinking and learning. KiP models students' knowledge as a fragmented and dynamic system as opposed to a coherent and stable one. To illustrate the utility of the KiP framework, I begin by highlighting one contemporary learning challenge that appears across STEM education: representational competence (RC). Broadly, RC refers to students' skills for interpreting, relating, constructing, and using disciplinary representations. I report on three research projects that examine students' RC in chemical and biological education. I leverage a mix of clinical interviews and experimental designs to demonstrate recurring challenges in RC. Notably, the relation between domain knowledge and RC is asymmetric—students' domain knowledge predicts their RC but it is difficult to find the reverse relation. These results echo that of seminal and contemporary investigations into RC and I therefore examine my claims in light of these investigations. Because of these recurring challenges, I conclude by contesting the theoretical status of RC. I argue that future investigations into students' interpretations and constructions of representations should be framed with learning theories more parsimonious than RC. The KiP framework offers ideas for these future investigations and I present some possibilities.

62. Tackling scientific misconceptions by fostering a classroom of scientists

Robert Denton*, The Ohio State University; Matthew Holding, The Ohio State University; Katherine Mollohan, The Ohio State University; Lin Ding, The Ohio State University; Judith Ridgway, The Ohio State University; Amy Kulesza, The Ohio State University

A basic component of science curricula is the understanding of scientific inquiry. While recent trends favor using students' inquiry to learn concepts with hands-on activities, it is often unclear to students where the line is drawn between the content and the process of science. To address this educational problem, we designed a laboratory activity that explicitly introduces students to the processes of scientific inquiry and allows the classroom to become a scientific community where independent studies are performed, shared, and revised. The learning goals of these techniques include demonstrating scientific methods as a non-linear processes and characterizing scientific endeavors in a more realistic way (creative, collaborative, and diverse). To measure this activity's efficacy, we conducted before and after surveys of attitudes toward the scientific process from students (N=293) who did and did not participate in the activity within multiple concurrent sections of an university introductory biology course. We measured student perspectives with both quantitative Likert-scale items and qualitative open-ended questionnaires. Analysis of variance of normalized student gains shows that students who entered the class with novice-like views of the scientific process showed a significant shift away from characterizing scientific methods as linear processes. For other survey items, students displayed attitudes that were more expert-like than predicted. Qualitative, open-ended surveys are being administered currently, and will be used to help explain these quantitative trends. Student comments and TA feedback reflect a positive reaction towards the freedom and realism provided by this activity's framework. Because we designed this activity to be relatively independent of the chosen content, we suggest that instructors can utilize this framework for classes of various disciplines and education levels as an effective way to introduce students to how real science happens.

63. Hypotheses for How Drawing as a Study Strategy May Impact Learning
Echo Lu*, UC Berkeley - Student; Elizabeth Sabiniano, UC Berkeley - Student; Diane Lam, UC Berkeley

This study investigates aspects of student-generated drawings that influence learning and retention of biology material. Forty-seven undergraduate students were split into two conditions: a "Drawing Group" trained to draw holistic models of biological systems, and a "Combined group" trained to self-explain, then draw. We collected 11 drawings per student as they used their respective strategies to study passages of text about the cardiovascular system. Our coding scheme then measured the frequency that three types of information were included in participant drawings: 1) labels (words that describe or identify structures and processes), 2) images (realistic or geometric representations of structures and processes), and 3) errors. We also coded for meta-representational aspects in each drawing, including the use of anthropomorphisms, metaphors, movement, color, legends, and the levels of abstraction. Preliminary analyses reveal a moderate correlation between number of labels used and learning gains about structure. We hypothesize that labeling requires identifying discrete parts of a system, which focuses attention on structure. We also found a weak to moderate correlation between the number of images drawn and learning gains about structures, pathways, and functions. This may be because pathways, (directions of blood flow) and functions (of various parts of the system), are easier to represent with images than labels. Finally, results demonstrate that while participants who drew more labels and images had more learning gains immediately after studying, they retained less information compared to the Combined Group after two weeks. We believe drawing may promote motor memory, easily lost without practice, while self-explanation may require connecting new concepts with prior knowledge, which would lend to retention. We hope our findings will add to the optimization of learning strategies that result in both immediate learning gains and long term retention of knowledge.

64. Peer coaches change the way students interact in clicker discussions
Jenny Knight*, University of Colorado; Sarah Wise, University of Colorado; Jeremy Rentsch, University of Colorado; Erin Furtak, University of Colorado

We have been investigating how students interact during discussions of clicker questions by transcribing and coding audio recordings of these interactions (see also Wise et al. abstract).

Here we describe the behavior of peer coaches (undergraduate learning assistants, LAs) when interacting with students, and investigate their potential impact on students' use of reasoning and questioning behavior. Student volunteers were from one section of an introductory molecular biology class. Volunteers were representative of the rest of the class and not different from each other in demographic measures (gender and year in school), although their GPAs were higher than the class average. Thirty-five transcripts of discussions among three groups of students included LA participation; an additional 30 transcripts from the same groups did not include an LA. We found no significant difference in the distribution of exchange of quality reasoning achieved by students in discussions with and without LA participation. However, students used significantly more questions requesting feedback when an LA was present. LAs used four behaviors in interacting with students: they prompted simple sharing of votes, asked questions to elicit reasoning, provided background, and provided reasoning. In 85% of student discussions, LAs used questioning to elicit reasoning. In response to LA questions, students provided additional reasoning statements in 50% of the transcripts. However, when LAs provided their own reasoning to students (in 45% of discussions), students rarely made additional reasoning statements. We will discuss the implications of these findings for training peer coaches, and for improving student discussion and learning in the classroom.

65. Concept inventory and clicker score trajectories as predictors of student success in large introductory biology courses

Un Jung Lee*, Stony Brook University; Stephen Finch, ; Minsu Ha, Stony Brook University; Ross Nehm, Stony Brook University; Gena Sbeglia, Stony Brook University; Qiaotong Zhang, Stony Brook University

Increasing the retention of STEM majors has recently emerged as a national priority in undergraduate education (PCAST, 2012). Although the reasons for changing from STEM majors are numerous, poor performance in large, introductory courses is one significant factor. In addition to implementing active learning and formative assessments, early interventions with struggling students could also be effective. Consequently, early prediction of student performance is key. Our study employed innovative statistical techniques (trajectory analysis) using data derived from validated concept inventories and clicker questions in order to determine the timepoint at which accurate predictions of student success could be determined. The diagnostic tests, administered to 287 participating students at the start of the semester, included two concept inventories and one attitude assessment (CINS, ACORNS, MATE). Clicker scores were also obtained for each of the 37 sessions. Our analyses revealed that diagnostic tests explained 29% of the variation in final grades; adding clicker scores for the first four weeks increased explained variation to 50%. The diagnostic tests and all clicker scores collectively explained 58% of the variation. The average of the first four weeks of clicker scores predicted a satisfactory or unsatisfactory final course grade for 76% of the students. The trajectory analysis identified three distinct clicker performance trajectories with consistently high, medium, or low clicker scores. These analyses indicated that clicker scores can be an important variable for predicting final course grade. More importantly, predictions with relatively high rates of accuracy could be made early in the semester. These results identify trajectory analyses of clicker scores as a potentially useful tool for identifying at-risk students in large, introductory biology (and other STEM) classes, although further studies in a diversity of instructional contexts are warranted.

66. Examining introductory and advanced undergraduates' understanding of systems biology concepts using the BioCore Guide

Christian Wright*, Arizona State University; Scott Freeman, ; Alison Crowe, ; Brian Couch, University of Nebraska - Lincoln; Michelle Smith, University of Maine; Jennifer Knight, University of Colorado - Boulder; Sara Brownell, Arizona State University

The Vision and Change report has provided a widely accepted framework of core concepts that are becoming increasingly integrated in undergraduate biology curricula. To broaden our understanding of students' mastery of these concepts, discipline-based education researchers have begun to establish the inaccurate understandings of undergraduate biology students as they relate to the five core concepts. Although many inaccurate student ideas based on the core concepts have been identified, the core concept of systems has yet to be fully explored. Due to its complexity and interdisciplinary nature, systems may represent a particularly challenging concept for students to master, particularly for lower division students with minimal exposure to the integrative nature of biological phenomena. To better understand students' mastery of systems biology and how students' thinking about systems biology changes throughout a four-year curriculum, we examined the inaccurate understandings of introductory (freshman and sophomore) and advanced (junior and senior) undergraduate biology majors at a four-year institution using the Vision and Change BioCore Guide. The BioCore Guide is a nationally-validated, grassroots-generated framework that provides a series of specific statements that expounds on the more general core concepts in the Vision and Change report. We then constructed 18 questions targeting the statements about systems from the BioCore Guide. Using think-aloud interviews that were transcribed and analyzed using grounded theory, we identified a novel set of accurate and inaccurate conceptions that introductory and advanced students harbored about the concept of systems, including "sticky" inaccurate conceptions that persisted in advanced students. Here we report our findings, which form the basis for establishing a learning progression for the core concept of systems, and discuss the broader implications of these findings for instructional and curricular reform efforts.

67. Agent-based modeling: A Technological tool for thinking and learning in biology education

Matthew Lira*, University of Illinois at Chi

Educational research is a design science rather than a natural science. As a design science, educational research aims to understand how different designs impact students' thinking and learning. NetLogo is an agent-based computer-modeling environment designed to afford insight into how lower-level agent-agent interactions produce emergent phenomena in complex, dynamical systems. Although agent-based modeling environments have been well explored in K-12 settings, much less work has been done at the undergraduate level broadly and in biology education specifically. The present study employed a qualitative experiment (n= 10) that assessed how different designs (narrated animation or quantitative simulation) impacted students' explanations of one emergent phenomenon: the generation of the resting membrane potential. Using a constant comparative method, students' explanations were categorized on the basis of the mechanisms they proposed (e.g. passive or active transport) and they domain knowledge they introduced (e.g. forces or energy). The results revealed that students who evidenced domain knowledge regarding passive mechanisms of transport and the balancing of forces comprehended mathematical aspects of the simulation (e.g. Nernst

potentials) that other students did not. In contrast, all students who experienced the narrated animation benefited similarly in that they comprehended the passive mechanism but gained no further insight into the mathematical models of the system. Leveraging these findings, I built an innovative learning environment that attempts to employ a learner-centered design. I present a series of fully functional agent-based models and learning activities designed to address the needs of the learners. I further discuss the affordances and constraints of building models with NetLogo specifically from the perspective of an educator and consider the benefit of future studies that allow students to engage in computer programming and model building.

68. Characterizing Students' Critical Analysis Skills of Primary Literature

Brian Rybarczyk*, UNC Chapel Hill; Blaire Steinwand, UNC Chapel Hill

Developing critical analysis skills is an important component of undergraduate science education. This study aimed to address the question: What is the extent and depth of students' critical analysis skills of experimental research? We hypothesized that upper-level students are able to provide, with practice, scientifically valid critiques of primary literature throughout a course. A coding scheme was generated to classify students' written critique statements of journal articles at the start of the semester, from group essays written during the semester, and from individual students' analysis of a journal article at the end of the semester. The scheme included primary codes related to non-scientific aspects (writing/organization) and scientific aspects (experimental design/results/conclusions). Secondary sub-codes were used to further classify each statement and assigned a connotation using sentiment analysis. Critique statements from 105 students across 6 semesters of the same course were coded by two raters independently with a consensus of 0.70-0.96 across the three codes. Results showed that initial critiques compared with critiques from group essays showed significant increase in scientifically-related statements ($p=0.0002$, Fisher's exact test) and a decrease in negative critiques ($p=0.0001$). Analysis of critiques at the end of the semester revealed a significant increase of scientifically-related critiques as compared to the start of the semester ($p=0.0345$) indicating that students developed effective critical analysis skills. Aspects of critical analysis that students did not extensively address were assessing the appropriateness/power of statistical analyses, proposing alternative methodological approaches, and disagreeing with authors' conclusions. These results reveal that upper-level students demonstrate effective critical analysis skills and reveal aspects they need to further develop as a part of critical analysis of experimental research.

69. Setting up for success: How effective are learning objectives?

Jessica Merricks*, University of Missouri; Bethany Stone, University of Missouri

Effective instruction should link learning goals, instructional strategies, and assessment in order to support student learning. Most instructors begin a unit of study by introducing students to the learning objectives and end with an assessment of students' mastery of those objectives. One may assume that students structure their learning strategies around the course learning goals; however, this assumption has not been tested empirically. In fact, few studies have explicitly investigated the relationship between students' use of learning objectives and their overall learning outcomes. Our goal was to determine the extent to which students use learning objectives as a tool for mastering course content. To address our question, we administered a series of surveys to non-science majors enrolled in a General Biology or an Infectious Diseases elective course. We surveyed students' knowledge on the unit content prior

to instruction. After the unit exam, we assessed students' content knowledge as well as their knowledge of the learning objectives. Finally, we surveyed the extent to which students used the learning objectives in preparing for their exam. We observed a clear link between students' use and knowledge of the learning objectives and their mastery of the expected content. We will discuss the implications of these results in the broader context of undergraduate science instruction. Our results suggest that it is critically important to present clear learning goals and to train students to use those goals as a framework for structuring their own learning.

70. Teaching controversial topics in science: Do undergraduates' attitudes relate to overall learning gains?
Jessica Merricks*, University of Missouri; Bethany Stone, University of Missouri

The AAAS Vision and Change initiative highlights the need for undergraduate instructors to focus on the relevance of science to students' everyday lives. Prior studies suggest that when students are not interested in the content, they are less engaged in the learning process, therefore it is important to account for the misconceptions, attitudes, and opinions students possess in order to maximize learning gains. This seems to be especially poignant in non-major science courses, in which students often do not see the relevance of the material to their personal lives or may possess strong opinions regarding certain controversial or divisive topics covered in science courses. Therefore, understanding the relationship between students' attitudes toward learning and overall learning outcomes is critical. Our research addressed the following question: Do students' prior attitudes towards the content relate to their overall learning outcomes? Our study subjects were undergraduates enrolled in either General Biology for non-majors or Infectious Diseases, a non-major's elective course. Prior to instruction, we surveyed students' attitudes regarding a specific topic covered in one unit in each course (genetically modified organisms (GMOs) or HIV/AIDS, respectively). We also assessed students' prior knowledge of the unit content before instruction began. After the unit exam, we reassessed students on their attitudes towards GMOs or HIV/AIDS and calculated their learning gains. Results varied substantially; however, we saw distinct patterns regarding overall learning gains. We will discuss these results and their potential implications for undergraduate learning.

72. Snapshot Serengeti: Authentic science for non-biology majors
Annika Moe & Craig Packer, University of Minnesota

Citizen science projects offer an opportunity to introduce the scientific process to undergraduates in non-science programs. These projects have been designed for general public use, bypassing many of the technological barriers to participating in authentic research without a prerequisite background in science content. We combined the zooniverse.org citizen science project, Snapshot Serengeti, with a guided curriculum to produce a six-week laboratory module. This module served as a vehicle for delivering an authentic research experience to non-biology majors at the University of Minnesota. During the fall semester of 2013, we piloted the module in two courses - Global Environment and Evolutionary and Ecological Perspectives.

73. Developing a Backup Plan: A Career Mentoring Course for Undergraduate Biology Majors
Julianne Winters*, Drexel University; Jennifer Stanford, Drexel University

Career-planning courses have previously been demonstrated to be effective career interventions, providing a number of gains for participating students. Though a career planning course for biology majors has been described in the literature, there has been little assessment of whether such a course allows students to effectively develop alternative career plans. A primary goal of developing a career-planning course to support biology majors at Drexel University was to have students develop an alternate career plan for their future careers. Previous assessments of our senior students revealed that few students develop a backup plan to their primary career goal. As a result, we wanted to develop additional opportunities to provide career mentoring early in the students' training, and to assess whether these opportunities allow students to effectively develop career plans. Developing a career planning course required in the sophomore year has been an efficient mechanism to provide career mentoring to our large cohort of undergraduate biology majors. We assessed students using a pre-test/post-test approach to assess whether the course increased the number of students that feel they have structured career plans. Based on these assessments, while 51% of students begin the course with a well-structured plan towards achieving their primary career goal, 93% of students end the course with such a plan. In addition, while only 37% of students enter the course with a clear backup plan, 83% feel that they have a satisfactory alternate career goal by the end of the course. Here we describe the structure of this course, and outcomes from implementation over the past two years. We believe a course of this type could be easily implemented in other disciplines and at other institutions to support students in the development of plans to support their career goals.

74. Rapid prototyping as a tool for project-based, interdisciplinary learning
Nadine Stecher*, Wentworth Institute of Techn.; Alyssa Payette, Wentworth Institute of Technology; Stephen Chomyszak, Wentworth Institute of Technology

The Wentworth Institute of Technology (WIT) is an undergraduate institution with a focus on teaching technical design and engineering. Most engineering students enroll in basic science courses. For example, students majoring in Biomedical Engineering are required to complete the Anatomy & Physiology course sequence. Recently, the teaching effort at WIT is moving towards an externally-collaborative, project-based, interdisciplinary curriculum (EPIC) for learning – experiential learning with the goal of career success. As part of the Anatomy & Physiology I course, we developed the pilot run of an interdisciplinary project that is meant to eventually replace the traditionally-taught laboratory portion of the course. The project concentrated on rapid prototyping, the fabrication of a three-dimensional scale model of an object with the help of specific computer software. This technique has become increasingly popular in the biomedical engineering industry. Through this project, students were given the opportunity to familiarize themselves with the rapid prototyping method and apply it to a biological concept. More specifically, students designed and ultimately printed a three-dimensional representation of a specific skeletal muscle. The project was accomplished in groups of 3-4 students and was co-taught by instructors of the Departments of Sciences and Mechanical Engineering & Technology. The summative assessment included an oral and written presentation of the project outcome in addition to the printed object, and the perception of learning gains were measured using a post-project student survey that also solicited comments from the students. This information will be used to improve and stabilize the reformed course structure.

75. Exam self-evaluation assignments reveal differences in metacognitive regulation development in introductory biology students

Julie Dangremond Stanton*, University of Georgia; Xyanthe Neider, Washington State University; Tori Byington, Washington State University

Alarmed by the percentage of students who do not pass introductory biology, we tested the hypothesis that providing opportunities for metacognitive development improves student performance. In Brown's theoretical framework, metacognition is divided into metacognitive knowledge: what we know about our own thinking, and metacognitive regulation: how we regulate our own thinking to facilitate our own learning. Using self-regulated learning as a lens, we targeted metacognitive regulation development by guiding students through open-ended self-evaluation assignments following the first and second exams in an introductory biology course (SE-1 and SE-2). We used a triangulated design to measure student metacognition and performance through these assignments, the Metacognitive Awareness Inventory (MAI) and course grades. Although MAI scores correlated with course grades, increases in MAI and exam grade averages following self-evaluation assignments were modest and inconsistent across three semesters. Interested in understanding how to better facilitate metacognitive development in introductory biology, we coded students' exam self-evaluation assignments (n=230) for evidence of the metacognitive regulation skills defined by Schraw: planning, monitoring and evaluating. In SE-1, we found that nearly all students were willing to take a different approach to studying, but showed varying abilities to plan, monitor and evaluate their study strategies. Although many students were able to outline a study plan for the second exam that could effectively address issues they identified in preparing for the first exam, only half reported that they followed their plan in SE-2. While motivation and beliefs about learning likely played roles, SE-2 responses suggest that students at this level may lack the metacognitive knowledge necessary for executing the study strategies they selected.

76. Community College Students demonstrate significant gains in self-rated attitudes, abilities, and epistemological beliefs after a single CREATE introductory science course

Sally Hoskins*, City College of CUNY; Alan Gottesman, CCNY; Kristy Kenyon, Hobart and William Smith Colleges

We hypothesized that intensive analysis of scientific literature through the CREATE strategy would produce cognitive and/or affective gains in community college students, as it has at 4-year colleges/universities. We trained community college faculty in the CREATE strategy (2012/2013 summer workshops) and followed them as they implemented the strategy at their campuses. Participating students took pre/postcourse anonymous tests assessing potential cognitive and/or affective gains. An outside evaluator independently assessed faculty and their students. We report here on outcomes of affective assessments: the SAAB test of student attitudes, abilities and beliefs (Hoskins et al., 2011; CBE LSE 10(4) 368-378), and the Student Assessed Learning Gains survey (http://www.salgsite.org/student).

SAAB outcomes showed significant gains, most with moderate effect sizes (ES), in students' self-rated ability to decode primary literature, interpret data, visualize, and "think like scientists" (n = 46). On epistemological belief categories, students made gains in their sense of science as creative, and in understanding of scientists and their motivations. Interestingly, both students who self-identified as Biology majors (n = 16) and those who did not (n = 30) made significant gains in multiple SAAB categories. On the SALG survey, individual statements grouped into "Understanding", "Skills", "Attitudes" and "Integration of Learning" subsets. The Biology majors made significant gains in the first three categories; the pooled group as well as the students who did not describe themselves as majors made significant gains in all categories (moderate to large ES). Attitude and confidence are important correlates of student performance. To our knowledge this is the first report indicating that scientific literature-focused courses can evoke shifts in attitudes and epistemological beliefs of a diverse pool of community college students. We thank the NSF for support (DUE 1021443).

77. Analysis of a Cell Model Project

Katie Shannon*, Missouri S&T

In my Cellular Biology course, students make a 3D model or website of a differentiated eukaryotic cell, and provide a short written description of their cell. There are several learning outcomes for this assignment. 1) Students will demonstrate mastery of the subject, but in a creative way rather than through an exam. This objective is based on the idea that students have different learning styles. 2) Students will obtain a greater understanding of cellular diversity. This objective is meant to counter a student misconception that all animal cells are round. 3) Students will show in their model the relationship between cell structure and function, which is a central concept in the course. 4) Students will gain a better comprehension of the functions of cell organelles, since they will depict all organelles functioning in a single cell. During the course, organelles are discussed individually, with details on the function of isolated organelles. This project is a chance for the students to integrate the parts of the cell into a whole system, and is at the synthesis level in Blooms' taxonomy. The purpose of this study is to determine if this assignment meets the learning objectives. In three semesters, students were given a variation of the assignment, either the model with a short paper, a paper with a drawing, or a paper only. The students took a pre and post-test and completed an attitudes survey. The written assignments were graded using a rubric. The study was designed to determine if having the students create their own representation of a cell (either a model or a drawing) increases learning over a written assignment alone. I will present the results and discuss pros and cons of each variation of the assignment. This approach could easily be adapted to many different biology courses.

78. Adventures in Flipping-Flipped Fridays in Cell Biology

Katie Shannon*, Missouri S&T

In the Fall of 2013, I flipped one day a week of my Cellular Biology course. For the flip, students were required to watch 2-3 short video lectures and complete an online quiz on the content before class. Class time was used for students to work in groups on a problem set. The purpose of doing the flip was to give the students practice with challenging questions that asked them to apply what they had learned and interpret representations of experimental data. Comparison of the flipped Friday class with the previous semester, which was traditional lecture three days a week, showed no difference in exam averages between semesters. Analysis of student video viewing patterns using Kaltura metrics showed that videos needed to be fifteen minutes or shorter, and that most students were watching the videos only once on Thursday nights. A few students did not watch any videos and many students viewed some but not all, or started watching the video but did not finish. Student comments on evaluations indicate that most students liked the flipped Friday approach, but there is also student resistance to the method. Benefits of the flipped Friday were increased student-student interaction, increased faculty-student interaction, and introduction of more challenging problems. Ideas to improve student engagement further will be discussed.

79. Beyond Punnett squares: transforming genetics learning in an inquiry-based introductory biology lab course

Janet Batzli*, University of Wisconsin-Madiso; Amber Smith, University of Michigan; Paul Williams, University of Wisconsin; Seth McGee, University of Wisconsin; Katalin Dósa, University of Wisconsin

What determines variation in phenotype (Pv=Gv+Ev)? Genetics instruction in introductory biology is typically confined to transmission of single-gene, discrete traits and avoids the complexities of variation in continuous, quantitative traits. We developed a new 4-week unit for an inquiry-based laboratory course focused on the inheritance and expression of a quantitative trait in varying environments. We utilized Brassica rapa Fast Plants as a model organism to study variation in the phenotype anthocyanin pigment intensity. Learning goals were to: 1.) develop and carry out an experiment about how artificial selection and environment influence Pv, and 2.) explain inheritance and expression of Pv using data as evidence. We used the threshold concept heuristic to frame our study of students' language acquisition, integration and explanations of concepts. Our research question was: To what extent does this inquiry-based genetics unit influence students' familiarity with language, concepts and explanations of inheritance and expression of a quantitative trait? For language familiarity, we asked students to do a word association task and self-assess their understanding of genetics concepts on a pre- and post-unit survey. We then analyzed students' final research posters to assess students' explanations of Gv, Ev and their influence on Pv. The word association task revealed progression and shift in genetics language familiarity from basic to more discipline-specific concepts. Given review of 53 student posters, we uncovered a spectrum of student explanations, with 50% capable of intermediate to high-level explanations and the other half relating low-level, inaccurate or incomplete explanations for how Gv and Ev can influence inheritance and expression of Pv. Our analysis reveals steps in a learning progression and identifies the importance of 'variation' and 'alleles' as transformative concepts for teaching and learning of genetics beyond Punnett squares.

80. Confusion surrounding the synthesis of macromolecules from building blocks: a crucial gap revealed

L. Kate Wright*, Rochester Institute of Technol; Dina Newman, RIT

The Central Dogma of molecular biology—which holds that information stored in DNA is copied to transient RNA molecules, which are themselves used to direct synthesis of particular proteins—is a foundational concept that can be problematic for students of biology. In order to improve student learning outcomes, it is necessary to determine precisely where confusion occurs. Numerous assessments and interviews of students at all levels were used to develop the first draft of the Central Dogma Concept Inventory. Students were drawn from introductory through advanced courses for in-depth validation interviews, which revealed what we hypothesize to be the foundational problem with student understanding of information flow: poor mental models surrounding synthesis of macromolecules from building blocks. Many students were confused about the difference between nucleotides and nucleic acids, and between amino acids and proteins, and tended to use the terms interchangeably. They had difficulty reasoning about molecular processes because they could not separate building blocks from final products. Their understanding of the terms "synthesis" and "catalyze" were especially vague. Students who gave a clear and accurate definition of "synthesis" were able to demonstrate expert-like reasoning. Cognitive theory describes learning as integrating new information onto a scaffold of prior knowledge. The results of this work point to a weakness in the scaffold that needs to be addressed in undergraduate biology education.

81. Development of a Central Dogma Concept Inventory for Use at All Levels of Undergraduate Biology

Dina Newman*, Rochester Institute Technology; L. Kate Wright, Rochester Institute of Technol

Without good assessment tools, instructors cannot know how effective they are being in the classroom; instructors cannot measure effectiveness of new instructional pedagogies; and "transformed classrooms" cannot continue to evolve. Numerous Concept Inventories and other instruments have been developed that include questions related to information flow. However, the available tools are not exhaustive, and a tool to measure deep understanding of the Central Dogma of Molecular Biology has not yet been developed. Building upon several years' worth of work surrounding student understanding of Central Dogma, we have developed a 24-item, multiple-select format instrument. We have used student language and ideas to construct the questions, and chose to use a multiple-select format in order to minimize student reliance on test-taking strategies and to reveal increasing sophistication of understanding when students recognize multiple good answer choices. We are currently in the process of validating with in-depth student interviews, and revising based on the results of those interviews and item-response analysis. Preliminary data suggests that this instrument may useful for identifying learning progressions related to the concepts of information flow in biology education. We anticipate implementing the instrument at multiple institutions with diverse student populations in the fall.

82. Relationships between DBER and Science Instruction: Perceptions from Stakeholders

Sue Ellen DeChenne, Univ. of Northern Colorado; devasmita Chakraverty, University of Nebraska-Lincoln; Marilyne Stains*, University of Nebraska Lincoln

There is a national recognition of the existence of a practice-research gap in science instruction in higher education. While extensive research has been conducted on the barriers that science instructional practitioners face in implementing best practices, there is little evidence about how the faculty involved in the change process view the relationship between DBER and science instructional practice. The purpose of this study is to explore that relationship. The guiding research question is: How do faculty involved in DBER and reformed science instruction view the relationship between DBER and science instructional practice? This study uses grounded theory to develop a model of this relationship. Forty eight faculty representing biology, chemistry, and physics have been interviewed. These faculty are variously involved in DBER, science faculty professional development, or are reformed science instructional practitioners. Preliminary results indicate that faculty think that DBER research and instructional practices should inform each other but that in practice it does not. Comparisons between engaged practitioners and DBER faculty of reasons evoked for the lack of relationship indicate opposite views on stakeholders' responsibility. Engaged practitioners expect DBER faculty to provide resources for teaching while DBER faculty feel that engaged practitioners have the responsibility to be aware of the research. Interestingly, most DBER faculty evoked a level of enculturation within DBER that informs their teaching philosophy and identified the 'faith-based' teaching philosophy of practitioners as barriers to instructional transformations.

83. Measuring the Effectiveness of an Exam Review Activity to Promote Self-Evaluation Skills in Introductory Biology Students

Kelly McDonald*, Sacramento State ; Gillian Andaya, Sacramento State ; Victoria Hrabak, Sacramento State; Sarah Parks, Sacramento State; Rafael Diaz, Sacramento State

Many instructors spend countless hours preparing exam questions that will provide an accurate gauge of student learning. They devote a significant amount of time to grading and providing feedback, with the intention that students will consider the comments, evaluate their mistakes, and learn from the experience. In reality, most students receive their exams, look at their grade, and skim the numbers to make sure that their scores were calculated correctly. We began implementing an exam review activity in an Introductory Biology course to help students learn from their mistakes and strengthen reasoning and self-evaluation skills. The goal of this study was to measure the effectiveness of the activity using student performance and attitudinal data. We developed and applied a strategy and rubric for measuring student performance based on the accuracy of the corrected exam, the degree to which students completed the assignment, and the quality of student responses to a prompt requiring reasoning skills. Data revealed that students could provide the correct answer 96.4% of the time when given the opportunity to re-work the problems, and nearly all students (98%) completed the assignment. However, approximately 40% of all responses received low quality scores, indicating that students may not be getting the maximum benefit from the experience. We also found that students struggled to accurately diagnose the nature of their errors, which could make it difficult to take corrective actions. Qualitative data from student attitudinal surveys were both positive and insightful. While our study supports the continued use of the exam review activity, our findings highlight areas in which students may benefit from additional structure and support as they build self-evaluation skills. We are currently investigating a possible relationship between the quality scores and performance and improvement on course exams in order to further tailor the activity to help struggling students.

84. Back to kindergarten? Student perception of course difficulty in active learning classrooms

Sara Wyse*, Bethel University; Paula Soneral, Bethel University

Increasingly, more college level biology courses are embracing active learning practices called for in reports such as Vision and Change. Although it is accepted that student learning and engagement increase with active learning, little is known about how students perceive academic difficulty in these courses. We administered an end-of-semester survey to 120 students enrolled in active-learning courses. Two of these courses were introductory level (Bio1 and Bio2) and one a 300-level molecular biology course (Bio300). Results from the qualitative results were coded for patterns by two raters with established inter-rater reliability. We compared distributions between the courses using Chi-Square. Students perceived active learning classes as both “hard” and “easy” due to increased cognitive demand coupled with peer and instructor support. Students defined active learning courses as easy because of the format of the learning (e.g., workload that seems manageable, content is logical and easy to follow, strong alignment between instruction and assessment, and high degree of faculty support). Simultaneously, students defined active learning as hard because they may not have entered the course with appropriate background knowledge and/or skills, and they find the cognitive demand of these courses to be difficult; patterns did not differ among courses (Chi-

Square, p=0.5, Cramer's V = 0.116). Results show that active learning courses, although often perceived and communicated as "easy" by students, are also seen as academically rigorous due to increased cognitive demand. Students recognize they are being asked to do more higher-order thinking, yet find the intrinsically student-centered nature of active learning helps them overcome the challenges associated with course difficulty. These findings highlight the importance of being aware of and responding to student perceptions of academic rigor as we continue to implement Vision and Change in undergraduate biology

85. Factors Impacting Student Success and Persistence in the Biology Major
Sue Ellen DeChenne*, Univ. of Northern Colorado; Jeffrey Olimpo, Univ. of Northern Colorado; Biscah Munyaka, Univ. of Northern Colorado; Susan Keenan, University of Northern Colorado

Many students who enter institutions of higher education with intentions to major in STEM fields have good GPAs and high aptitude and achievement scores. However, a large proportion of these individuals leave STEM fields by switching to non- STEM majors or leaving college without earning a degree. Although there have been several studies broadly addressing departure from STEM disciplines, none has specifically concentrated on the biological sciences, despite a national retention rate of about 50% for biology students. Appropriate remedies for biology attrition cannot be devised without comprehensive knowledge of the causes of such attrition. In order to address this need, we are conducting a quantitative study to identify potential factors impacting student success and persistence in biology. Success is indicated by introductory biology course grades and persistence is defined as enrollment in sophomore-level biology coursework. Academic and motivational variables have been collected from more than 400 introductory biology students. Multiple linear regression was used to determine important variables in success in first semester biology. Results indicate that academic factors (students' index score, ACT composite score, SAT math score, and high school GPA) and motivational factors (self-determination, self-efficacy, and intrinsic motivation) each uniquely predict success when input into a linear regression model. Factors which impact retention will be determined using probit analysis as soon as fall semester registration is finished (at the end of April). These preliminary results suggest that both pre-college and student characteristics may be important factors for further research aimed at success and persistence of students in biology major.

86. Is the money worth it? SCALE-UP classrooms in the changing face of higher education
Sara Wyse*, Bethel University; Paula Soneral, Bethel University

National calls to reform instruction have catalyzed the development of pedagogies and facilities to help students become practicing scientists and/or scientifically literate citizens. Student-Centered Active Learning Environments for Undergraduate Programs (SCALE-UP), implemented in more than 175 universities, facilitate learner-centered pedagogies; however, they are costly to build and maintain. In light of the current crisis in higher education, can we afford such expensive classrooms? Specifically we ask: What component(s) of the SCALE-UP classroom do students and faculty view as most helpful to their learning or teaching? Through open-ended survey questions and a faculty focus group, we asked "what aspects of the SCALE-UP classroom help your learning or teaching?" Surveys were administered to students at the end of the semester in which they were enrolled in a course in a SCALE-UP classroom; specifically for students in introductory biology and chemistry, communications, and upper-level education, and social work courses. We used grounded theory to determine coding categories and then coded the results. Three classroom components emerged as critical for faculty and students: (1) whiteboard space, (2) round tables, and (3) multiple sight lines for viewing. For students in introductory biology (n=39) the whiteboard space (40%), having multiple sight lines (27%) and round tables (20%) were most helpful to their learning. This pattern was also seen with 300-level students (n=35) where the round tables (40%), multiple sight lines (38%) and writable walls (14%) were most valuable to their learning. These results also suggest that the more costly component, the connection of the round tables to the main teaching station, is least valuable to faculty and students. If this trend holds, perhaps SCALE-UP classrooms can be constructed for less without sacrificing the learning experience. Such changes could enable more widespread adoption of such learning spaces.

87. Designing Graduate Programs for Interdisciplinary Learning: Lessons from the UC Davis IGERT Julia Gouvea*, UC Davis; Cynthia Passmore, UC Davis

In recent years there has been increased discussion about the need to train graduate students to think, talk and conduct research that crosses disciplinary lines in order to address complex socio-ecological problems. There is widespread recognition that traditional models of graduate education do not provide adequate support for interdisciplinary learning (Golde & Gallagher, 1999; Graybill et al., 2006; Moslemi et al., 2009). The National Science Foundation (NSF) invested in the Integrative Graduate Education and Research Traineeship (IGERT) program and awarded grants to universities in order to "establish new models for graduate education…that transcend traditional disciplinary boundaries." Now that the program has ended, what have we learned about how to design for interdisciplinary learning at the graduate level? In this poster we explore the question: what does it look like to intentionally design a graduate education program to foster interdisciplinary learning? We present an analysis of an innovative model of IGERT training developed at UC Davis. One novel aspect of this model is that IGERT trainees were fully responsible for choosing, scoping, designing and enacting an interdisciplinary project. We use interview data from both graduate student trainees and faculty trainers to distill the affordances and constraints of various features of this open-ended project model for interdisciplinary learning and discuss the implications for interdisciplinary learning more broadly. Through this analysis we uncover and explore a number of design tradeoffs for graduate training and from there we propose a set of design considerations for those hoping to support interdisciplinary learning.

88. Flipping the Genetics Classroom Improves Student Attendance, Engagement, and Teamwork Heidi Sleister*, Drake University; Gina Digiantonio, Drake University; Amanda Wollert, Drake University

A flipped classroom approach was implemented in a sophomore-level introductory genetics course in response to national recommendations for improving science education. While a variety of active learning strategies improve student performance and engagement, there are few published examples of flipped undergraduate genetics courses that use a team-based learning (TBL) approach. Student performance, attendance, and engagement in an introductory genetics course were compared in semesters with a flipped approach (using TBL) and a non-flipped approach. The non-flipped semester included lecture and small group informal interactions, whereas the flipped semester included less lecture and more student teamwork with TBL. For TBL, permanent six-member teams completed five TBL units, each consisting of pre-class preparation, individual assessment (iRAT), team assessment (tRAT), and an application exercise. The impact of this approach on student performance, attendance, engagement, and satisfaction was analyzed by comparing exam scores, iRAT / tRAT scores, and student attitudes. While average exam scores in semesters with and without TBL were similar (85.9% vs 85.1%; t-test p=0.45), students reported the approach was helpful for learning. As expected, team (tRAT) scores were significantly better than individual (iRAT) scores (98% vs 84.4%; t-test p < 0.001). Student attendance and engagement were better in the flipped semester versus non-flipped semester (average 1.5 vs 4.1 days missed; t-test p = 0.01). Student surveys during the flipped semester revealed polar attitudes. Students who liked the flipped approach enjoyed the in-class activities and teamwork, while those that disliked the approach complained about pre-class preparation and (in some cases) having a dysfunctional team. While student outcomes in the TBL classroom were generally positive, this active-learning approach was challenging due to increased instructor workload and initial student resistance.

89. The benefits of both structure and flexibility: Evidence of student learning from intermediate constraint assessment tools

Denise Pope*, SimBio; Kerry Kim, SimBio; Jody Clarke-Midura, MIT; Susan Maruca, SimBio; Eli Meir, SimBio

Large introductory biology classes present many challenges to providing meaningful and engaging learning opportunities for students. One challenge is posing questions that require higher-order thinking and complex answers from students, and providing them with feedback that is both specific to their responses and timely. Multiple-choice assessments allow for automated feedback but do not allow for flexible answers, while open response assessments can capture the complexity of student thinking, but implementing immediate feedback is difficult. We are developing intermediate constraint formative assessment tools for use in computer-based activities, such as virtual labs and tutorials. These tools (which we call LabLibs and WordBytes) provide more structure and constraint than open response, but allow for more flexible and complex answers than multiple-choice. LabLibs is a multiple-fill-in-the-blank tool with drop-down menus, and WordBytes is an answer construction tool where students build responses from a pool of words and phrases. The more constrained nature of LabLibs makes it relatively straightforward to categorize all possible answers and write feedback for them, but WordBytes poses a much greater challenge for implementing answer scoring and feedback. We have used two approaches for algorithm development for WordBytes scoring, and will compare the costs and benefits of each approach. The LabLibs and WordBytes tools were implemented in two SimBio virtual labs in Fall 2013 and Spring 2014 semesters. We have data from over 1,000 students at multiple schools each semester. By analyzing student initial responses as well as their subsequent response after receiving feedback, we can assess the effectiveness of these tools in aiding student learning. Results suggest that the majority of students learn effectively from these tools, but they prove challenging for about 5-10% of students. The data suggest our approach is a promising avenue for further development.

90. "In biology we never explain that": Exploring a student's epistemological stances towards physics and biology

Julia Gouvea*, UC Davis; Benjamin Geller, University of Maryland, College Park; Benjamin Dreyfus, University of Maryland, College Park; Vashti Sawtelle, University of Maryland, College Park; Chandra Turpen, University of Maryland, College Park; Joe Redish, University of Maryland, College Park

There is an ongoing perception that undergraduate biology courses emphasize rote learning of facts and procedures (e.g. Momsen et al 2010), but less is known about how students perceive what it means to learn and know in biology. A growing body of research across science disciplines suggests that these "disciplinary epistemologies" can influence how and what students learn in a discipline (e.g. Hammer, 1994; Watkins & Elby, 2013).

Survey research (Hall, 2013) suggests that viewing biology as a fact-driven discipline is a relatively common stance among biology majors and can be resistant to change, even in the face of instructional reforms. While surveys can measure the prevalence of such views, they can do little to uncover the mechanisms that contribute to their formation or change. Our objective is to better understand the stability and potential consequences of such views. We present an in-depth case analysis of Gavin, a student from an interdisciplinary physics course for life science majors, who repeatedly referred to biology as a discipline that describes "what," but not, "how" or "why."

Our case study relies on an analysis of a series of five interviews conducted with Gavin over two years (with triangulation across additional data sources where possible). Our findings demonstrate that Gavin's "naïve" stance towards biology contrasts with a more "expert-like" stance towards physics: Gavin describes physics as place where he can understand "how things work" inside him and around him. What this analysis suggests is that Gavin demonstrates aspects of a sophisticated epistemology of science, which are productive for working towards understanding, not just memorizing. We discuss the implications of this study for understanding how both researchers and educators might tap into these epistemological resources in order to help students like Gavin recognize the centrality of explaining how and why in biology.

91. Illustrating the expert-novice continuum in graph construction in biological sciences
Aakanksha Angra*, Purdue University; Stephanie Gardner,

Graphs are useful data analysis and communication tools and applying quantitative reasoning is important for all undergraduate students. The purpose of our study is to understand the reasoning implemented by upper and lower-level undergraduate students, graduate students, and professors when choosing and creating graphical representations of biological data. We used a triangulated study design, grounded in the constructivist theoretical framework, grounded theory for our methodological framework, and the Concept-Reasoning-Mode model as our analytical framework. During semi-structured interviews, participants were randomly given one of two biological scenarios with a data table and asked to construct a graph. Analysis of verbatim interview transcripts suggests several differences in graphs produced and reasoning used by students and professors. When asked to construct a graph, 77% of the undergraduate students chose to plot either all of the dataset or part of it in raw data form, while 13% plotted complex, transformed data. Most undergraduate students (64%) preferred to construct a line graph. Most graduate students constructed scatter plots (60%) and 50% plotted complex data. Professors did not construct scatter plots, but 67% plotted complex data. When asked why they made a particular type of graph, 32% of the undergraduate students reasoned with specific reference to their graphs (mode) whereas 45% of graduate students and 17% of professors did so. Professors were more likely to use a variety of concepts and their mode when providing the reasoning for their graph choice. When asked to create another graph using the same dataset, many students reflected on their first graph and struggled to create a different graph. By characterizing graphical reasoning along the novice-expert continuum, our findings will provide a rich source of insight for the construction of a diagnostic tool to improve instructional approaches in the area of data analysis and graphing.

92. Pathways over Time: An adaptable course based undergraduate research experience for introductory students

Douglas Warner, Boston College; Todd Reeves, Northern Illinois University; Michael Wolyniak, Hampden-Sydney College; Clare OConnor*, Boston College

A growing body of evidence supports the importance of research experiences in the undergraduate biology curriculum. Course based research experiences (CUREs) offer opportunities to introduce large numbers of students to research experiences. The goal of the Pathways over Time project was to design an introductory level CURE that would be sustainable and adaptable to a variety of laboratory environments and instructor backgrounds. The Pathways project developed at Boston College (BC) involves students in a semester-long functional genomics investigation into the phylogenetic conservation of the enzymes involved in methionine biosynthesis. During the semester, students learn and practice basic techniques of microbiology, molecular cell biology and genetics. Conservation of MET gene function is tested by cross-species plasmid complementation of S. cerevisiae met deletion strains. Student learning is assessed with pre-lab quizzes, lab notebooks, oral and poster presentations, database and literature assignments, and a series of "micro-reports" that are assembled into a final research report in the format of a scientific publication. Pre- and post-course evaluation instruments include concept tests and student self-assessed confidence and learning gains. Comparison of pre- and post-course confidence data show statistically significant gains in measures associated with experimental design, technical proficiency, written and oral communication, database usage and ability to use and understand primary literature. The adaptability of the Pathways project was tested during the spring semesters of 2013 and 2014, when a modified version of the BC course was offered at Hampden Sydney College (HSC). HSC students used course materials and tutorials posted on the BC course site. Evaluation instruments showed similar gains in content knowledge and self-assessed competencies.

93. Improving the Alignment of a Virtual Lab on Natural Selection to Students Understanding and Misconceptions

Jody Clarke-Midura*, MIT; Denise Pope, SimBio; Susan Maruca, SimBio; Kerry Kim, SimBio; Eli Meir, SimBio

Despite years of research on student misconceptions around evolutionary theory, educators still struggle with how to help students overcome their confusions about evolution. We have been revising an interactive simulated laboratory (“Darwinian Snails”), which is designed to teach natural selection, in order to better understand student misunderstandings and help them overcome them. In this study, we redesigned the lab by improving the alignment of the content of the lab with our learning objectives, focusing on revising in-lab formative assessments to target common misconceptions and key concepts in natural selection. In the process, we integrated two types of interactive formative assessment questions that provide feedback in real time into the lab. We used pre-post assessments (α=0.75) to measure students’ learning gains. The assessment questions come from three published and validated measures. Our sample consisted of 1004 students (63% female) at seven universities and colleges, who used the revised simulation primarily in large intro biology courses during the fall of 2013. Students who used the improved lab showed statistically significant learning gains for all learning constructs ($t=23.88$, $p < 0.0001$) with an effect size of 0.6. We also saw a statistically significant decline in misconception usage from pre to post assessment that we have not seen in previous research. In this poster, we will present details about our revision of the lab, as well as our findings on the concepts and misconceptions around natural selection.

94. Conceptual framework alignment between textbooks and primary literature

Andrea Bierema*, Western Michigan University; Renee' Schwartz, Western Michigan University

The National Research Council Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century published BIO2010: Transforming Undergraduate Education for Future Research Biologists (Washington, D. C., The National Academies Press, 2003). The committee suggested that alignment occur between the current research and undergraduate education. Unfortunately, alignment has been rarely studied in college biology, especially for fundamental concepts. Therefore, the research question for this study was: to what extent do the conceptual frameworks of the primary literature for animal behaviour align with undergraduate animal behaviour textbooks? The conceptual framework for the field of animal behaviour was established by Tinbergen 50 years ago in his paper On Aims and Methods of Ethology (Zeitschrift Tierpsychologie, 20, 410-433, 1963). The framework suggests integrating four main questions while studying behaviour: causation, ontogeny, survival value, and evolution. The current study utilized content analysis to collect data on how often these four questions are addressed in journal articles of 2013 (from the five animal behaviour journals with the highest citation index report) and the four most commonly used textbooks in the United States (determined by a stratified random sample of 99 institutions). It was found in both the primary literature and textbooks, more than 75% cover two of the four questions: causation and survival value. Although this trend indicates an alignment between primary literature and textbooks, both are misaligned with the intended framework. Therefore, if the intended framework is ever to be established in the field of animal behaviour, new editions of textbooks must incorporate more ontogeny and evolution concepts. This study is of interest to SABER attendees because it illustrates a need to study how established conceptual frameworks are actually being utilized in the research community and educational resources.

95. An Integrative Case-based Approach to Evolution Education

Peter White, Michigan State University; Merle Heidemann, Michigan State University; James Smith*, Michigan State University

Our team has developed, implemented, and tested the effectiveness of integrative curricular cases designed to help undergraduate biology students understand evolutionary processes and principles. We had two major objectives in our design strategy. First, we sought to address the “silo effect” that is still the norm in many Introductory Biology course sequences, with students learning principles isolated from their overall biological context. Second, we sought to incorporate the molecular and cell biology components of evolutionary processes into undergraduate biology curricula, explicitly tying DNA replication and mutations to population-level evolutionary processes. We used a pre/post assessment in eight post-secondary biology courses to test our hypothesis that student understanding of evolution can be enhanced when students learn biology in a context where integrative evolution cases are used ($n = 593$ students). Four of these courses used cases interwoven into the existing curriculum, and four of these courses did not. We found that students who learned biology in courses using the integrative cases performed significantly better on an evolution assessment tool that we designed and validated for the purposes of this study. Student improvement in understanding evolution was evident both in introductory molecular courses and introductory organismal courses, and appeared to be dose-dependent. Students who used integrative evolution cases during two different semesters scored highest on the evolution assessment (Tukey HSD test, p = 0.049). Taken together, our data indicate that an approach to evolution instruction that integrates evolutionary principles and concepts across the two Introductory Biology semesters can enhance student learning. The cases we developed are housed at www.evo-ed and our materials are freely available. Dissemination is ongoing, and we generate approximately 6,000 page views per month, with materials accessed by users in 49/50 US states.

96. Assessing graphical competency in an upper-level physiology laboratory course
Aakanksha Angra*, Purdue University; Stephanie Gardner,

The purpose of our study is to understand the reasoning implemented by undergraduate biology students when choosing and creating graphical representations of physiological data in a naturalistic setting. Data are reported from students enrolled in an upper-level physiology course with a laboratory component using social constructivism as our theoretical framework. Four times over the course of the spring 2013 and 2014 semester, student teams emulated the scientific process by designing their own experiment, collecting their own data, analyzing the data, and presenting those data to the class in brief presentations. After teams presented their findings, students were asked to individually reflect on their graph choice and the advantages and disadvantages of their graphical representation. Written and verbal responses were coded using inductive thematic analysis and evaluated with inter-rater reliability. Preliminary findings show that the majority of students constructed scatter plots (38%), followed by bar graphs (32%), line graphs (21%), and box and whisker plots (9%). When students were asked to explain their graph choice, responses fell into three main themes dealing with variables, comparison, and descriptive and inferential statistics. When asked to list advantages and disadvantages, responses fell into five main themes: comparison, graph construction, graph interpretation, statistical concepts, and communication. Upon further analysis, we discovered that students gave incorrect advantages and disadvantages, which fell into the themes of graph construction, interpretation, statistical concepts, and communication. We will be conducting semi-structured interviews with students at the end of the semester to give them an opportunity to elaborate on their written reflections. This naturalistic study is part of a larger triangulated study and will support the construction of a diagnostic tool that will assist educators in teaching graphing.

97. A Mixed-methods Analysis of Assessment Formats in an Undergraduate Anatomy and Physiology Course
Adriel Cruz*, California State University, S; Kelly McDonald, California State University, Sacramento

Summative assessments hold high stakes for students since they are a supposedly objective measure of students' true abilities and student performance on these assessments determines prospects for future classes and careers.   In this study, students (n=34) in an undergraduate anatomy and physiology course took three types of summative assessments – multiple-choice, written short answer, and oral. The questions covered concepts of hemodynamics in the context of diabetes and included varying difficulties of questions according to Bloom's Taxonomy.   Correlation analysis shows poor correlation between the multiple-choice format to the written format (R2=0.05, P=0.202) and the oral form at (R2=0.012, P=0.543). Correlation between the written format and oral format shows good correlation ($R2=0.473$, $P < 0.001$), but qualitative analysis of the oral transcripts shows that students may be earning points they do not deserve. For instance, when asked to describe how high blood sugar would affect blood pressure, students related concepts such as blood viscosity and resistance. However, when later asked to define these terms, they could not give an adequate definition. Qualitative analysis also showed that some students came to "correct" conclusions through incorrect logic. Some assume that excellent performance on written summative assessments is also indicative of a student's ability to orally communicate their knowledge, a competency described in Visions and Change. However, attitudinal data from this study show that many students do not feel comfortable in their abilities to orally communicate, regardless of their grade. Overall, this study highlights some of the shortcomings of multiple-choice and written open response assessments.

98. Early Exposure to Research: Benefits for STEM and Non-STEM Populations

Jennifer Stanford*, Drexel University; Jaya Mohan, Drexel University; Suzanne Rocheleau, Drexel University

Undergraduate research programs are common on many college and university campuses, but careful assessment of the outcomes of these programs is a fairly recent endeavor. Several large-scale studies have evaluated and described the benefits of undergraduate research. These studies have primarily focused on the benefits of undergraduate research for the STEM population. The Students Tackling Advanced Research (STAR) Scholars Program at Drexel University provides research experiences to first-year undergraduate students in both STEM and Non-STEM disciplines. In the 12 years since its establishment, the STAR program has paired more than 1,000 students with over 300 faculty mentors. We have assessed outcomes of STAR Scholars using the Undergraduate Research Student Self-Assessment (URSSA) tool. Through these assessments, we wanted to ask whether our student population made the same learning gains as those described in the literature, and whether there were any differences in outcomes amongst STEM and Non-STEM student populations. Here we will describe the structure of the program, participant demographics and outcomes over the past twelve years. Benefits were observed for both participating students and faculty mentors. For faculty, benefits include greater productivity as well as the ability to work closely with highly capable and motivated students. For students, benefits of participation include increased retention (96% retention rate for STAR Scholars), and learning gains in all areas studied. Most importantly, we found very few statistically significant differences in learning gains or motivations for conducting research between STEM and Non-STEM student populations in over fifty different items studied, focused on personal and professional gains, becoming a professional, attitudes about the experience, and motivations to conduct research. This suggests that early research experiences can benefit both STEM and Non-STEM student populations.

99. Institutional Data for Data-driven Decision-making: Introductory Biology Model

Sarah Jardeleza*, Michigan State University; Rebecca Matz, Michigan State University; Cori Fata-Hartley, Michigan State University

We describe a model for using institutional data to drive the decision making process in course and curriculum reform. The model is described using an example from ongoing efforts to reform Cell and Molecular Biology, the first course in the introductory biology sequence at

Michigan State University. This is one of the first targeted steps of the broader MSU Biology Initiative, a college-wide effort to improve biology education at MSU. Although data derived from measuring student learning outcomes are important, they do not provide a complete understanding of the situational factors that can impact student outcomes in a given course or program. The institutional data evaluated here are critically important to address questions related to enrollment needs, student demographics, and program tracking. The data analyses described in this model and example are used to help "close the loop" in evaluation of the broader MSU Biology Initiative. Specifically, the data are used to decide where resources would be best allocated and which interventions might improve overall success and retention for biology majors. For those interested in learning more about how to access institutional data at their institutions, suggestions and resources are also discussed.

100. Small World Initiative: Crowdsourcing antibiotic discovery to enhance student learning

Paula Soneral*, Bethel University; Sara Wyse, Bethel University

The Small World Initiative (SWI) developed at the Center for Scientific Teaching at Yale uses an undergraduate research course framework to crowdsource searching for new antibiotics. Students culture soil microbes, screen for antibiotic activity, perform 16s rRNA gene sequencing, and chemically extract metabolites. As they take ownership of the project, students learn scientific process skills and core cell and molecular biology concepts. We piloted the SWI in an introductory biology class at Bethel University and ask, to what extent did the SWI improve learning outcomes, retention, and attitudes about biology? Learning gains were measured using the Classroom Undergraduate Research Experience (CURE) survey pre-post implementation of the curriculum. We also measured the progression of student attitudes using the Colorado Learning Attitudes about Science Survey (CLASS-BIO). Lastly, we examined student performance on selected items from the Introductory Molecular and Cellular Biology Assessment (IMCA), and student retention in the course. Initial CLASS-BIO measurements of agreement with expert attitudes for 100-level SWI students (N=48) showed significant differences in all categories at the start of the SWI curriculum compared to a control group of senior biology majors not affiliated with SWI (N=21) (overall % favorable=71.3 and 79.8 respectively; >3 SEM). IMCA items administered as in-class clicker questions showed an average normalized learning gain of 0.7 (mean pre-test=45.2 +/- 0.6 SEM; post-test=87.6 +/- 0.5 SEM; p< 0.01 one-way ANOVA; N=58), and by mid-semester retention in the course was 100%. These preliminary data suggest that the SWI is a relevant and realistic model for course-based biological research, resulting in higher retention rates and learning gains. The SWI has the potential to help early undergraduates accelerate their progression from novice to expert thinking in biology, while increasing overall retention in the discipline.

101. Structured testing improves the effectiveness of retrieval practice in an undergraduate genetics course

Yunqiu Wang*, University of Miami; Gavin Leighton, University of Miami

Recent research in cognitive science has suggested that the act of retrieval enhanced memory, and the process of reconstructing knowledge through retrieval practice produces greater gains in meaningful learning than elaborate study activities centered on rote memorization. The present study tested retrieval practice in an undergraduate genetics course over a period of two semesters, the spring semesters of 2011 and 2013. In spring 2011 we employed retrieval practices in the genetics class online via Blackboard TM. The test questions used in the practice were neither organized nor grouped by their difficulty level. As a result no significant learning gains were achieved. In spring 2013 we modified the retrieval practice strategy in the same genetics course. We implemented an online test bank with 750 questions into the course. By answering these questions students had multiple opportunities to practice information retrieval and knowledge reconstruction throughout the entire semester. Additionally, we adjusted the level of question to the learner to avoid student boredom or frustration from questions that were too simple or difficult. As students answered the multiple-choice and fill-in questions, we provided online access to hints and links to specific reference materials (e.g. e-book pages), and immediate feedback after each question. We analyzed the data using generalized linear mixed models and selected the best models based on information criteria. The results showed a strong, positive correlation of the improved and structured retrieval practice with students' learning gains as measured by the post-to-pre test improvement score and all test scores. We conclude that while retrieval practice can be beneficial to student learning in principle, but, a well structured and comprehensive testing scheme is also necessary and imperative to ensure the success of retrieval practice as an effective tool to promote conceptual learning about science.

102. Instrument Development to Assess Student Conceptual Understanding in Biology

Tawnya Cary*, University of Wisconsin; Caroline Jakuba, University of Wisconsin; Janet Branchaw, University of Wisconsin

The Vision and Change report (AAAS, 2011) recommends that biology educators structure undergraduate teaching around five conceptual themes, or core concepts, to support student development of a cognitive framework for learning biology. However, validated instruments to assess student conceptual understanding of the proposed core concepts do not exist. The purpose of this study is to develop a validated instrument to assess student understanding of the Vision and Change core concepts. Specifically, we are investigating 1) whether students spontaneously generate a cognitive framework that aligns with the Vision and Change core concepts and, 2) whether students are able to use the Vision and Change core concepts to facilitate their learning of biology. To answer these questions, we used a think-aloud, interview format with 30 undergraduate students who were nearing completion of their Introductory Biology coursework. Each student was asked to complete a series of activities including the newly developed conceptual theme instrument, card sorting tasks designed to capture student conceptual understanding in biology (Smith et. al., 2013), and distractor tasks. Participants were video recorded in order to capture their thought processes as they talked out each activity, and scores were assigned based on each student's ability to complete the instrument and card sorting tasks according to a pre-determined rubric. The development of a validated instrument will allow bioscience educators to access student understanding of the Vision and Change core concepts, and determine whether students apply a cognitive framework around the Vision and Change core concepts when processing biological information.

103. The MACH model for explaining molecular mechanisms: themes across multiple disciplines

Caleb Trujillo*, Purdue University; John Alaniz, Purdue University; Trevor Anderson, Purdue University; Nancy Pelaez, Purdue Universiry

Constructing explanations is an essential part of the life sciences. This study addresses the question, "What are the essential aspects of biology experts' explanations of cellular and molecular mechanisms within their domain?" To address this question we first built on previous work and our own thought experiments to derive an initial model about mechanistic explanations. Secondly, we tested the validity of the initial model by asking seven biologists from various subdisciplines, to explain a cellular mechanism of their choice. Data was collected from interviews, artifacts and drawings and subjected to thematic analysis. We found that biologists: use our initial mechanistic model of molecular explanation by focusing on entities, activities, and organization. But in addition, they highly contextualize and constrain their explanations according to biological and societal significance; integrate explanations with the methods, instruments, and measurements they use to investigate; and use narrative stories along with analogies to explain their systems. These themes informed a modified model of expertlike explanations of cellular mechanisms. Expert explanations consider four components: the Methods (M), Analogies (A), Context (C), and How (H) the mechanism works. Our model will provide a foundation for future work in life science education research, as well as other science domains, and offers a way to teach explicitly about components of biological mechanisms.

104. Introductory biology students' gene-to-phenotype models reveal difficulties articulating information flow within the central dogma of molecular genetics

Adam Reinagel*, Saint Louis University; Kolin Clark, Saint Louis University; Ranya Taqieddin, Saint Louis University; Elena Bray Speth, Saint Louis University

The mechanism by which genes determine phenotype is complex and presents a considerable challenge for learners, for it requires understanding how information contained in molecules determines physical characteristics of organisms. A model-based strategy for teaching and learning about the gene-to-phenotype (GtP) relationship was employed in an introductory biology course at a large private research university. Students were iteratively asked to construct conceptual models that explain how genotype determines phenotype for a variety of scenarios in which mutation introduced variation in a population. We identified four key processes—mutation, transcription, translation, and phenotype expression—as essential to convey a complete account of information flow within GtP models. We investigated introductory biology students' ability to (a) represent the four key processes within their models, and (b) incorporate each process in a way that accurately conveys GtP information flow. Analysis of GtP models produced by students in 4 consecutive iterations of the course revealed that students consistently incorporated transcription and translation in their models with high frequency and in an apparently appropriate way, while frequency and accuracy of the processes of mutation and phenotype expression were consistently lower. Over the course of the semester, however, students improved in their ability to appropriately connect mutation and phenotype expression within their models. We further investigated whether facility for accurately incorporating the concepts of transcription and translation was due to students simply memorizing these words without grasping their mechanistic meaning. Thus, in the last course iteration, students were asked to articulate the gene-to-mRNA and mRNA-to-protein relationships without using the root words transcription and translation. Analysis of this data will reveal students' mechanistic thinking of the central dogma of molecular genetics.

105. Attending and responding to student thinking in written work

Cynthia Hill*, Tufts University; David Hammer,

Research on learning and teaching in biology education, and in science more generally, has emphasized the importance of instruction eliciting and engaging with students' reasoning. Thus, a number of accounts have discussed how instructors attend and respond to the substance of student thinking in classroom conversation. There has been less attention, however, to how instructors might engage with student reasoning in the context of written work: Most studies focused on student writing in biology have focused on matters of scientific style, rather than on the writing as evidence of students' conceptual understanding. Research in mathematics education, by contrast, has paid significant attention to teachers' exploration of student reasoning through written work. In this study, we examine how instructors, specifically university teaching assistants (TAs), attend and respond to student thinking in the context of students' written work. The data are laboratory reports with TA comments from an introductory biology course at Tufts University, as well as transcripts from interviews of the TAs about their reading and commenting on these reports. For this presentation, we examine student work and commentary from one TA, "Abby*," who, among TAs we have seen, was among the more attentive and responsive to student thinking. We show evidence of Abby's attending and responding to multiple aspects of students' writing, including textbook correctness, genre, and clarity, as well as the substance of their thinking. We discuss the challenges and possibilities of conducting this research at larger scale, how different kinds of writing may be more effective at eliciting students' genuine thinking, and, finally, how graduate instructor training could include a component focused on interpreting and responding to student thinking in written work. *Pseudonym

106. Systems Biology Education Construct Development

Jennifer Eklund*, Institute for Systems Biology; Brady Bernard, Institute for Systems Biology

All post-secondary students should be afforded high quality opportunities to learn the content and practices of systems biology, and be introduced to course pathways and careers that will allow them to succeed in this field. The sequencing of the human genome and affiliated technologies has catalyzed a shift in the practice of biology. As highlighted in A New Biology for the 21st Century, a "new biologist" collects vast amounts of data and then interprets the data to understand the behaviors of complex biological systems. These contemporary practices are exemplified by the emergence of systems biology. Students with preparation in systems biology will have the skills and opportunity to be a part of the future solutions for some of today's most complex problems: health, global climate change, world nutrition, and sustainable energy. The purpose of our study is to create a validated list of systems biology concepts to support the creation of curriculum, instruction, and assessment in the field of systems biology. We conducted 6 semi-structured interviews with systems biology experts and reviewed systems biology textbooks and syllabi to create an initial list of concepts for validation. Additionally, we informally interviewed over 10 other systems biology and biology education experts. Analysis of results indicate that both core concepts or content and core competencies or practices are necessary for systems biology understanding (Vision and Change, 2011). Subsequently, we have probed over a dozen specific concepts including ideas around emergent properties, robustness in systems, and network characteristics using a survey with a Likert-like scale to ascertain accuracy and importance. Data from the initial interview and the survey was used to create a list of core content that is both accurate and important for systems biology education.

107. Attempting Biology Department-wide Professional Development in Scientific Teaching

Gloriana Trujillo*, San Francisco State University; Carmen Domingo, San Francisco State University; Shannon Seidel, San Francisco State University; Kimberly Tanner, San Francisco State University

Research suggests that convening groups of professional peers grappling with similar teaching challenges is key in promoting iterative, on-going professional growth and pedagogical change (Lave, 1991; Loucks-Horsely, 1998). However, many higher education reform efforts limit their aspirations to engaging only a few interested faculty within a single department. Additionally, there appear to be few to no published attempts to engage faculty across an entire biology department in pedagogical change. With funding from an HHMI Undergraduate Science Education grant, we are attempting such department-wide, collaborative professional development in scientific teaching. While we have hypothesized that the majority of biology faculty will participate, we have been struck by consistently low expectations about likely participation by those external to the institution. As such, we report here data suggesting that engagement of large proportion of biology department faculty is possible. Of the many findings from the first year, we share five here: 1) 95% (36/38) of faculty and 88% (23/26) of lecturers participated in one or more brief Scientific Teaching Workshops. 2) 71% (27/38) of faculty and 77% (20/26) of lecturers participated in a weeklong Scientific Teaching Institute. 3) Of Institute participants, 79% additionally participated in post-institute, semester-long teaching collaborations. 4) Institute alumni predicted these new ideas would most influence their teaching: equitable teaching strategies (65.6%), backwards design (59.4%), stereotype threat (59.4%), and Vision & Change (59.4%). 5) Finally, 91% of first cohort institute alumni (n=32) asserted interest in attending an advanced Scientific Teaching Institute. While investigation of the impact of this professional development on classroom practice and student learning is in progress, these initial findings suggest that systemic professional development efforts within biology departments are possible.

108. Student Perceived and Determined Knowledge of Biology Concepts in an Upper-level Biology Course

Brittany Ziegler*, MNSU; Lisa Montplaisir, NDSU

To be an effective learner, students should recognize what they know and what they do not. This study examines the relationships between students' perception of and determined knowledge in an upper-level biology course using a pre/post-test approach. On the pre- and post-test students indicated how they perceived their knowledge and demonstrated through a written response their knowledge of biology concepts and terms. The written responses were evaluated to determine student knowledge. The mean score for student perception was significantly higher than their determined knowledge on the pre-test ($t[68] = 10.36$, $p < 0.0001$) and post-test ($t[70] = 9.8145$, $p < 0.0001$). Alignment between student perception and determined knowledge was significantly more accurate on the post-test compared to the pre-test ($F1, 38 = 8.5258$, $p = 0.0059$, $R2 = 0.1833$). There was a significant difference between the pre- and post-test for student perception of their knowledge ($\chi 2[4, N = 1728] = 353.998$, $p < 0.0001$) and determined knowledge ($\chi 2[4, N = 1727] = 250.870$, $p < 0.0001$) with responses coded at higher perception and determined knowledge levels on the post-test. Students in the upper-quartile had alignment between their perception and determined knowledge that was significantly more accurate than students in the bottom-quartile on the pre-test ($\chi 2[7, N = 479] = 101.237$, $p < 0.0001$) and post-test ($\chi 2[4, N= 479] = 4.735$, $p = 0.3156$). However, bottom-quartile students did not perceive their knowledge differently than upper-quartile students on the pre-test ($\chi2$ [4, N= 479] = 4.735, p = 0.3156) or post-test ($\chi2$ [4, N= 3364] = 1.526, p = 0.8220). This study provides evidence that discrepancies exist between what students perceive they know and what they actually know which can have substantial implications for student learning. Accuracy in monitoring one's self-knowledge is a critical component of the learning process.

109. Computer-based and hands-on simulations of natural selection – equally effective and engaging?

Caleb Rounds*, University of Mass Amherst; Denise Pope, SimBio; Jody Clarke-Midura, MIT

Natural selection is notoriously difficult to teach, given the common misconceptions that persist, even after instruction. One approach to helping students learn the key concepts of natural selection is to allow them to simulate the process of evolution by natural selection in a laboratory exercise. A classic lab exercise used in many schools across the country simulates natural selection in successive generations of predator and/or prey populations using a hands-on activity. In the simulation, assorted dried beans represent the prey and the students act as predators, using a variety of tools. An alternative approach uses computer simulations of virtual populations to allow students to visualize and manipulate the process of natural selection in lab exercises. Many of these computer simulations also focus on the evolution of predator defenses in prey populations. In this study, we compare a hands-on simulation exercise ("Clipbirds") and a computer-based simulation exercise ("Darwinian Snails"). Our objectives are to compare learning gains and student engagement in the lab activities, since an ideal lab would both engage students and enhance their learning. In a large introductory biology laboratory class (over 900 students), half of the sections were randomly assigned to each of the lab exercises. Students in all sections had the same pre-lab and post-lab assignments, as well as a pre- and post-lab concept inventory, allowing us to compare student performance on the concept inventory and assignments. Our analysis focuses on key natural selection concepts, common misconceptions about natural selection, and transfer of concepts to a new context. We assess student engagement in the exercises with classroom observations, a self-report engagement survey, and a survey of teaching assistants, and our analysis compares each of these measures of student engagement.

110. More than flipping the classroom: a theory-driven approach to redistributing the cognitive load.

Elena Bray Speth*, Saint Louis University; Laurie Russell, Saint Louis University; Jennifer Momsen, North Dakota State University

The flipped classroom, in which students learn material before class on their own and then apply concepts and solve problems during class time, is becoming an increasingly popular learner-centered instructional strategy. However, few specific guidelines are available to inform instructional design in a flipped classroom. We are interested in developing a theoretical framework to guide distribution of content and activities in ways that enable students to learn actively and effectively both in class and at home. Based on literature on cognitive load and on learning about systems, we articulated a theory-driven approach to design a flipped introductory biology course. Our design is informed by the Structure-Behavior-Function framework, previously described and adapted to develop model-based pedagogy for introductory biology. Guided by this theoretical framework, we distributed learning activities, shifting the least cognitively challenging aspects of biological systems out of the classroom.

Students learned about structural components of biological systems and acquired vocabulary and definitions prior to class, through pre-recorded lectures, readings, and homework assignments. In class, students worked on problems and activities uncovering the more cognitively challenging mechanisms underlying biological systems' functions. We piloted the SBF-guided flipped classroom design in a large-enrollment first-semester introductory biology course at a private research university. We will describe how theory guided our implementation of a flipped classroom design and we will outline an instructional unit (on cell structure and function) as a representative exemplar of this instructional design. We hypothesize that distributing learning about structural and mechanistic/functional aspects of biological systems with this flipped classroom design will reduce the cognitive load students experience in class, which in turn will facilitate student engagement and learning.

111. Using 3-D visualizations to help with understanding of protein and enzyme structure and function

Colleen Conway*, Mount Mary University

Tutorials were developed to enhance the visualization and thinking in three dimensions of students in an organic and biochemistry course. These on-line tutorials were developed in a collaboration between a senior biology student and a professor under the CREST (Connecting Researchers Educators and Students) Project. One of the goals of the CREST Project is to make educational materials. These on-line tutorials used pdb files of proteins and highlighted features like active sites and catalytic groups to help students think in 3-D. Students' knowledge about both proteins and enzymes was assessed before and after using these tutorials. The assessments were a list of questions about the material covered. There was a statistically significant difference in the student knowledge pre and post the use of the tutorials using a paired t test with $p< 0.001$ for both tests). Many students struggle with visualizing proteins in three dimensions because they typically see only two dimensional images in their textbooks. These tutorials were created to improve this visualization and hopefully also learning.

112. Student engagement and learning outcomes in a flipped introductory biology course.

Laurie Russell*, Saint Louis University; Elena Bray Speth, Saint Louis University

The flipped classroom is a learning environment where students arrive to class prepared to engage in interactive problems and activities. Students process content on their own at home, prior to class, and practice applying concepts individually and collaboratively, through instructor-guided activities, during class time. This model is rapidly gaining popularity at the K-12 and college levels, but evidence of efficacy and specific guidelines for instructional design remain scarce. We designed and piloted a flipped instructional design in a large-enrollment first-semester introductory biology course for science majors at a large private research university. Instructional design was informed by cognitive load theory and by theory and evidence about learning about complex systems. The course was divided into five large sections of about 130 students each. One section implemented the flipped classroom intervention in addition to a model-based pedagogy (flipped, model-based); two sections implemented the intervention but not the model-based pedagogy (flipped), and two sections implemented a traditional, didactic pedagogy (non-flipped). For all five course sections, we collected evidence of (a) student learning outcomes (measured as performance on identical multiple-choice questions on the final exam), (b) changes in student approaches to learning and studying biology (ASSIST survey, completed at the beginning and end of the semester), and (c) student engagement in the classroom (self-reported end-of-term survey data). Preliminary analysis of our data in aggregate revealed that students in the flipped course sections were highly engaged in the classroom and performed at least as well as students in the non-flipped sections on the final exam.

113. Using a concept inventory in population dynamics to evaluate the effectiveness of an interactive in-class activity

Malin Hansen*, University of British Columbia

Population dynamics and related concepts such as exponential growth, logistic growth and population regulation, are often difficult for students due to their quantitative nature. Because these concepts require an ability to interpret graphs and mathematical models, and to convert numbers to rates, students need ample of time practicing such skills. In traditional lectures instructors may use graphs and models to teach the above concepts without knowing if students understand how to interpret them and without giving students opportunities to practice with feedback from peers and instructors. I developed a concept inventory (CI) with 17 questions in population dynamics that assess students' ability to interpret graphs and mathematical models. The questions were validated using student interviews and feedback from experts. I used the CI to test students' skills before instruction to learn about students' background knowledge and after instruction to evaluate the effectiveness of two different instruction methods: 1) a traditional lecture which gave no explicit opportunity for students to practice drawing and interpreting graphs, and 2) an activity which included several opportunities for students to draw and discuss their interpretation of graphs and models. The overall normalized learning gain ([post score – pre score]/[total score possible – pre score]) after the activity was 40% (an increase in average score from 40-64%) compared to 18% (an increase in average score from 42-52%) after the traditional lecture. The CI also revealed that learning goals specifically related to exponential growth was well addressed by the activity (a learning gain of 79-82% on related questions), but less so by the lecture (a learning gain of 10-22%). This newly developed CI allows instructors to evaluate the effectiveness of their instruction of concepts that often pose problems for undergraduate students in ecology.

114. Insights from introductory biology students' conceptual models of the gene-to-phenotype relationship

Ranya Taqieddin*, Saint Louis University; Elena Bray Speth, Saint Louis University

One of the core concepts of biology is the flow of genetic information; students should become fluent with the structural and functional definition of genes, and how they determine phenotypes. Articulating the genotype-to-phenotype (GtP) relationship is challenging for introductory biology students, as it requires biological language appropriation and integration of concepts and mechanisms at multiple levels of biological organization. In a large introductory biology course at a private research university, students iteratively constructed box-and-arrow conceptual models representing their understanding of how genetic variation arises and how genes determine phenotypes, in a variety of contexts. Student-generated GtP models were used to investigate students' reasoning. We analyzed in depth patterns of change in GtP models produced by one cohort of students (n=97) over the course of one semester. Change was measured as differences in: (1) the biological accuracy of individual propositions within students' models; (2) relative frequency and accuracy of propositions that represent either structural or functional /mechanistic relationships, and (3) models' ability to represent flow of genetic information from genes to phenotype. We found that students entered the course with a baseline understanding of structural relationships (i.e., "genes are composed of nucleotides"). Students' ability to incorporate accurate functional connections within GtP models (i.e., DNA is transcribed into mRNA) significantly improved early in the semester, and was maintained throughout. Incorporating allele and mutation, and making explicit the protein-to-phenotype connection proved to be particularly challenging for learners. In-depth understanding of how students' GtP models progress over time reveals learners' challenges and will enable instructors to specifically target learners' needs.

115. StarCellBio: a new molecular and cell biology experiment simulator
Alison Brauneis*, MIT; Lourdes Alemán, MIT; Ivan Ceraj, MIT; Shloka Kini, MIT; Chris Kaiser, MIT; Graham Walker, MIT

Acquisition of scientific reasoning is crucial for students' ability to accomplish real-world scientific tasks, including designing and conducting scientific investigation. Students struggle with learning and understanding the experimental design process, which requires authentic research activities. To provide students with real experimentation opportunities, faculty, research scientists, and software developers at MIT developed a freely available, web-based cell and molecular biology experiment simulator called StarCellBio (http://starcellbio.mit.edu/). StarCellBio enhances student learning of core cell biology concepts and experimentation by providing opportunities to design, perform, and analyze their own simulated experiments using three experimental techniques: western blotting, flow cytometry, and microscopy. To develop the simulator, we used an iterative, multi-faceted design process incorporating focus groups, prototype testing, user interface and graphic design, and usability testing. The result is a user-friendly, educational, and inquiry-based simulator that introduces research experiences into cell and molecular biology courses, compensating for the dearth of laboratory components in upper-level undergraduate cell and molecular biology courses at MIT and other institutions. Affective interview and survey data following StarCellBio implementation in MIT's Cell Biology course indicate that StarCellBio helps students develop a deeper understanding of experimental design and analysis, but that students struggle with proper experimental control design, a finding that we are currently probing in more detail. A cell biology experimental concept survey is under development to assess StarCellBio's effectiveness at enhancing student understanding of cell biology experimentation. Once fully disseminated, StarCellBio will support students' learning of cell biology concepts and experimentation in both residential and online courses around the world.

116. TA active learning training positively impacts student achievement and attitudes towards biology
Chris Pagliarulo*, UC Davis; Erin Becker, UC Davis; Erin Easlon, UC Davis

Although active learning techniques are known to improve student learning gains, adoption in college classrooms has been slow. Here we show that short periods of training are sufficient to enable teaching assistants lacking any formal pedagogical background to implement effective active learning classrooms and positively impact student learning and attitudes towards biology. Seven teaching assistants (pilot TAs) for an 1100-student introductory biology course participated in a 3-day intensive pre-course training in the use of active learning techniques, followed by weekly two-hour practice sessions. Six control TAs received traditional content focused pre-course and weekly training. Pilot discussion students completed online reading assignments and interactive modules prior to class. The discussion session itself was split into two parts: 1) a 30-60 minute high-intensity warm-up involving cold-call multiple-choice and open-ended questions; and 2) a 60-90 minute group work session utilizing case studies and/or POGIL-style activities. Control students completed pre-readings and quizzes and attended traditional 2 hour lecture and worksheet based discussions. Systematic classroom observation [COPUS instrument] confirmed consistent and intensive use of active learning techniques in all pilot discussions. Pilot students saw significant learning gains over control in difficult topic areas including replication, central dogma, and gene expression, scoring nearly one grade level higher than control on the respective lecture midterm. Control students scored more "novice-like" in their thinking pre-post in nearly every CLASS-Bio category. Overall, pilot students regressed significantly less pre-post and improved significantly in the areas of problem solving, persistence, engagement, and creativity. Results of the pilot study have prompted 80% of introductory biology faculty to seek out active learning training, with plans to implement in their next teaching cycle.

117. Teaching basic and advanced genetics concepts with an instructor-customizable genetics experiment simulator, StarGenetics

Lourdes Alemán*, MIT; Alison Brauneis, MIT; Ivan Ceraj, MIT; Graham Walker, MIT; Chris Kaiser, MIT

The Vision and Change Report urges higher education institutions to provide early research opportunities through discovery-based laboratories and research-instilled coursework. While numerous undergraduate research opportunities exist at the MIT, the traditional sequence of undergraduate biology courses primarily lacks integrated research opportunities. As a result, faculty, developers, and research scientists at MIT developed freely available, online biology digital learning tools for use in biology courses at MIT and worldwide. One such tool, StarGenetics (http://star.mit.edu/genetics/), is an instructor-customizable, Java-based genetics experiment simulator in which students are exposed to genetics concepts, reasoning and experimentation. In StarGenetics, students learn about the inheritance of traits by designing, performing, and analyzing their own crosses between model organisms, such as fruit flies, yeast, and Mendel's peas, as well as non-model organisms, such as cows. Instructors use StarGenetics to teach a wide range of genetics concepts that range from very simple, such as genotype and phenotype, to more complex ones, such as suppressors/enhancers and epistasis. The use of this simulator has dramatically changed how genetics concepts are taught at MIT, in particular because distilling certain concepts into text-based problems that students can answer causes false experimental scenarios to be presented, which are not normally encountered in a real lab environment. To provide genetics students with a meaningful learning experience using StarGenetics, we developed a successful implementation strategy through an iterative approach to arrive at the correct combination of the assignment type, assignment goals, credit, as well as required StarGenetics functionality. Successful implementation of StarGenetics has positively contributed to students' learning of genetics experimentation and analysis at MIT.

118. Assessing students' ability to trace matter and energy using lexical analysis of written assessments

Luanna Prevost*, University of South Florida

Working at large scales, such as the ecosystem level, can pose a challenge to students. This difficulty may lie in applying foundational scientific practices such as the conservation of matter and energy and tracing matter and energy across scales. Undergraduate biology students are often expected to master these foundational practices in introductory courses. In this study, I assessed introductory biology students' ability to trace matter and energy across an ecosystem using written assessments. Writing assessments allow students to express their knowledge in their own words, and may allow better insight into students' mental models. However, in large enrollment courses, written assessments are seldom used as they can be difficult to administer and grade. To overcome this barrier to assessing writing, I used computerized lexical analysis of writing assessments to examine student thinking about matter and energy in an introductory biology course. Students were prompted to write explanations for flow of matter and energy in an ecosystem. I analyzed 170 responses using lexical analysis to extract key concepts from student writing and cluster analysis to determine the groups of students' responses. Lexical analysis identified several ideas in student responses including energy loss, thermodynamics, and trophic levels (e.g. primary consumers). Cluster analysis of the students' revealed that students held varying models. For example students in one cluster explained that energy was not recycled but lost as heat from the system, with 11% of student referencing laws of thermodynamics. The analysis also identified mixed models of understanding that may be carried over to upper level courses. For example, 15% of students converted energy to matter along with correctly describing of how matter cycles through the ecosystem. Student mental models uncovered by this analytic approach are shared with instructors to provide them with feedback on student thinking.

119. Teaching faculty to fish: New approaches and evidence of effective professional development in learner-centered teaching - FIRST IV

Diane Ebert-May*, Michigan State University; Terry Derting, Murray State University; Timothy Hinkel, Valdosta State University; Jessica Maher, Michigan State University; Jennifer Momsen, North Dakota State University; Heather Passmore, Murray State University

Challenges in training faculty in inquiry-based, learner-centered instruction include empirically evaluating the efficacy of the training in teaching practices and sustaining long-term support for change. Faculty Institutes for Reforming Science Teaching (FIRST IV) provided new approaches to professional development in biology instruction for 201 postdoctoral scholars. The goal of FIRST IV was to develop early-career biology faculty who value and implement evidence-based pedagogies that facilitate student learning. We report on the activities and outcomes of FIRST IV, using comprehensive evidence derived from expert reviews of participants' teaching, self-reported data from participants, data from students, and comparisons with non-project faculty. FIRST IV participants completed a 4-day workshop twice in two years, followed by teaching an entire or partial course at their institution and sustained mentoring by experts in STEM education. Postdocs showed belief in learner-centered teaching, and 75% used learner-centered instruction when teaching actual courses. We also followed a subset of participants into their first faculty positions and quantified how their instructional design and student assessments differed from those of a colleague at the same institution. Although self-reported data indicated no differences in faculty perceptions of their teaching, external review of classroom teaching showed that FIRST IV faculty practiced significantly more learner-centered instruction and used more collaborative learning than did their colleagues. We conclude that the FIRST IV model offers significant and unique contributions to professional development in STEM education, because our approach and rigorous assessment process differs from typical workshops and shorter professional development programs that, like FIRST IV, aim to improve teaching practices of STEM faculty; importantly, FIRST IV faculty can fish.

120. Assessing the Impact of Molecular Modeling Curricular Tools on Student Performance and Attitudes

Michelle Harris*, University of Wisconsin-Madiso; Margaret Franzen, MSOE Center for Biomolecular Modeling; Robin Forbes-Lorman, UW-Madison; Javier Velasco, UW-Madison

The use of hand-held physical models has been shown to increase interviewed students' ability to answer high-order, challenging conceptual questions about molecular structure → function relationships. It is not clear, however, if the combination of models and online interactive tutorials using "3-D-like" molecular imagery is associated with student attitudes and summative performances on exams and quizzes. The UW-Madison's Biology Core Curriculum (Biocore) Program is one of several MSOE Center for BioMolecular Modeling partners in the NSF-CCLI funded CREST (Connecting Researchers, Educators, and Students; NSF #1022793, #1323414) program assessing modeling material effectiveness. We used a backwards-design framework to align our teaching goals with learning objectives, instructional activities and assessments in two honors biology courses. In one course students were randomly assigned to either a control group or to a treatment group with exposure to protein models and/or online tutorials. Student attitudes were assessed with pre- & post SALG surveys, and performance was assessed using short answer exam and quiz questions requiring students to use a conceptual model of a protein they had previously investigated to make predictions about an unknown protein. We have preliminary evidence that physical models and detailed imagery are viewed favorably by students, and allow them to practice several key cognitive skills associated with biochemical visual literacy. However, our small sample size in spring 2013 hampered our ability to make firm conclusions about our research question. We repeated our study in spring 2014 and also implemented physical models into the curriculum of a second, honors capstone course. We present here our aggregated data sets and conclusions. Further, we found that faculty involved in the creation/implementation of modeling materials have gained unique insights into student learning and adjusted their teaching approach accordingly.

122. Vision and Change Freshman Seminar Tackles the Achievement Gap Caroline Jakuba*, University of Wisconsin; Tawnya Cary, Univeristy of Wisconsin-Madison; Janet Branchaw, University of Wisconsin

Participation in first-year seminar courses has been shown to improve student retention and academic success, especially for members of underrepresented minority populations. Exploring Biology, a high enrollment, first-year seminar course at UW-Madison, prepares students to become successful learners of biology, and develops their awareness of and participation in biology co-curricular learning experiences. Designed around the recommendations of the 2011 Vision and Change report, this course utilizes the 5 Core Concepts to introduce the breadth of biology and support students' development of a conceptual framework to guide their learning of biology in subsequent courses. Using a mixed methods approach we are investigating the impact of Exploring Biology on student performance, retention, and co-curricular engagement in the biosciences. A quantitative comparison of students' academic success, as measured by final grade in sophomore level Introductory Biology, indicates that underrepresented ethnic minorities and first-generation students who took Exploring Biology have fewer adverse outcomes in Introductory Biology than a matched control group of students. Interestingly however, Exploring Biology students as a whole do not show significant gains suggesting a differential benefit for at-risk student groups. Qualitative data, currently being collected from Exploring Biology alumni in their junior and senior years, is examining students' perceptions of how Exploring Biology influenced them, particularly their involvement in other High Impact Practices, engagement in biology-based learning communities, and continued use of the 5 Core Concepts in upper division biology courses. Results will identify the components of Exploring Biology that had particular impact on student success, and guide future studies on specific factors (e.g. development of science identity or self-efficacy, increased sense of belongingness) affected by the practices and experiences.

123. Drawing on student knowledge in human anatomy and physiology
Tara Slominski*, North Dakota State University; Lisa Montplaisir, North Dakota State University

Structure-function relationships are ubiquitous in biology and should be present in all levels of undergraduate biology curriculum (AAAS, 2011). Unfortunately, previous research indicates that students struggle with function-based concepts and are unable to use structural features to inform functional phenomenon. In Human Anatomy and Physiology (HA&P), students often attempt to master material through memorization of isolated facts instead of correlating structural characteristics with functional roles. Drawing prompts students to depict structures in service of a given function, exposing the level to which they understand structure-function relationships. Similar to open-ended prompts, drawings can reveal more about student understanding and alternative conceptions than multiple-choice questions. Despite their value, drawings are rarely used in HA&P. This study used student-generated drawings to investigate what students know about structure and function in a HA&P course. Two open-ended questions were presented to a large lecture course and students were instructed to answer through drawings. Specifically, we asked students to depict (1) synaptic transmission between two neurons in a linear pathway and (2) temporal and spatial summation on one neuron. Nearly 73% of students (n=358) created drawings suggesting inaccurate or incomplete understanding of synaptic transmission (1). When asked to illustrate summation (2), roughly 4% of students (n=323) were able to produce a relatively correct drawing and only two students were able to clearly depict both spatial and temporal summation. Data gained from this research can inform both practitioners and researchers about the prevalence and nature of the difficulties students have with learning physiology-based concepts and can inform future curriculum on the nervous system. Data collected here also advocate for further investigation into how student-generated drawings can reveal student thinking. Drawings collected here uncovered alternative ideas that were somewhat unpredictable and would not have been easily captured in a typical multiple-choice assessment.

124. Developing Understanding of Evolution in Complex Contexts
Jennifer Doherty*, Michigan State University; Laurel Hartley, University of Colorado Denver; Cornelia Harris, Cary Institute of Ecosystem Studies; C.W. (Andy) Anderson, Michigan State University

We are interested in how understanding biological principles enable students to predict and explain how ecosystems respond to disturbance. Research suggests most students are poorly prepared for this challenge. Here we focus on reasoning about the mechanisms of and limits to acclimation and adaptation in the complex scenarios that often occur with disturbance (e.g., when traits provide advantages in contexts more complicated than predator-prey scenarios with strong selection pressures, when traits are continuously variable or phenotypically plastic). Our goal is to develop a learning progression framework to describe how students' reason about the evolutionary aspects of ecological disturbance. We developed semi-structured interviews to solicit explanations in three disturbance contexts and administered them to students (6th grade-graduate, n=53). We used grounded theory to analyze interview transcripts and uncover emerging patterns. We identify and characterize two progress variables for a learning progression framework: The nature and origin phenotypic traits: 1) Less sophisticated students described the appearance and heritability of traits due to the wants/needs of the organism. 2) More sophisticated students traced the appearance of traits to random mutations and distinguished learned behaviors from inherited traits. 3) The most sophisticated students described genetically-controlled plasticity, understanding the ability to change in response to the environment is itself an inherited genetic trait. Selection pressure: 1) Less sophisticated students understood beneficial traits as increasing an organism's overall well being. 2) More sophisticated students understood that beneficial traits increased reproductive success, but only under strong selection pressures. 3) The most sophisticated students saw traits under both strong and weak selection pressures as important for reproductive success. This work suggests that in order for students to understand how

125. Exploring ways to overcome misconceptions about genetic linkage and molecular markers

Jennifer Klenz*, University of British Columbia; Lisa McDonnell, University of British Columbia

Genetics students struggle with the concept of molecular markers and their use to map genes to specific locations on chromosomes by applying linkage analysis. The aim of our project was to 1) capture common student errors and difficulties related to using molecular markers to map the location of genes, and 2) determine the impact of working through an ill-defined problem, compared to a well-defined problem, on student understanding. The ill-defined problem was designed to prompt students to draw upon a fundamental understanding of segregation and genetic linkage, and required students to construct for themselves an approach to use molecular markers to assess genetic linkage. This ill-defined problem followed the constructivist model (Lord, 1998) such that interpretation was required, the problem was more open-ended with multiple correct approaches. In contrast our well-defined problem was still challenging, but scaffolding was provided to guide the students through their analysis to the single correct solution. Students in a 200 level genetics course completed either the ill-defined problem set (n=103) or the well-defined problem set (n=200) during their weekly tutorial. All students then completed the same tutorial quiz to assess their ability to explain and use molecular markers for linkage analysis. Characterization of common errors made by students in both groups revealed significant difficulty in predicting segregation patterns for molecular markers that are linked, or not, to a gene of interest. Our results have implications for instructional design to improve student understanding in this area, and for the development of problems that will help students overcome common difficulties, and be better equipped to solve ill-defined problems using molecular markers for genetic linkage analysis. We will share these results as well as the impact on student understanding of using a third modified problem set.

126. Addressing Misconceptions in Tree Thinking

Tyler Kummer*, Brigham Young University

Tree thinking is a vital skill in understanding the evolution of diversity. Tree thinking is defined as the ability to visualize evolution in tree form and to use tree diagrams to analyze evolutionary relationships. Reading the tips of trees, node counting, ladder thinking, and equating similarity with relatedness are the four major misconceptions that have been identified in the literature. These misconceptions inhibit both the interpretation of trees and the understanding of their evolutionary implications. Previous research on this topic demonstrates that traditional biology curricula fail to address these common misconceptions. The Great Clade Race by Goldsmith (2003) is a lesson designed to specifically address these common misconceptions in tree thinking. We examined the effectiveness of this lesson by comparing sections of an introductory biology class. Four sections were chosen at random to be taught using The Great Clade Race. The remaining sections were taught using the traditional lesson which consisted of receiving instruction on phylogenetic principles and then building a phylogeny using characteristics of animal skulls. Each section was given a common assessment designed to assess tree thinking. Results and educational implications are discussed.

127. Potential of Digital Storytelling (DST) in the Biology Laboratory
Nancy Russell*, Georgia State University; Maggie Renken, Georgia State University; Julia LeCher, Georgia State University

Numerous reforms in our Introductory Biology lab for non-majors have aimed to create a laboratory curriculum that nurtures active learning. The curriculum changes emphasize conceptual understanding of biology and include the incorporation of digital literacy and involvement of the student as an agent of change. Typical students today are digital natives and are accustomed to interacting with large amounts of knowledge transmitted via multi-media platforms (Rapetti & Cantoni, 2013). Digital Storytelling (DST) merges digital literacy and storytelling and has proven to be a highly effective pedagogical method. This is in part because DST engages students while also promoting conceptual understanding and critical thinking skills (Yang&Chang, 2013). Despite this evidence, prior research on DST in higher education is limited, and empirical consideration of the use of DST in undergraduate biology classrooms is almost non-existent. An important consideration of DST in the undergraduate classroom is whether or not it can be used to evaluate student learning. We conducted a mixed methods study exploring the potential of DST to encourage students to think deeply about biology content. Thirty-one students from two lab sections of an Introductory Biology course for non-majors participated in the research. One group completed digital stories (DS) as a required assignment, while the other group completed essays on the same topic. Students' exam scores, DS/essay scores, perceptions of DST and essays, and DS files were collected. We analyzed data to determine if there is any significant difference in overall course achievement, learning of biological concepts, and student perception as a result of developing DS versus essays. With regard to student achievement, DST participants had significantly lower lab exam scores than participants in the essay group. We expect this reflects issues related to student motivation, and an ill fit between DS and traditional tests of rote memory

128. Chinese Biology Ph.D. Students' Perceptions of their English Proficiency: An Exploratory Case Study
XUAN JIANG*, Florida International Univ

There are thousands of Chinese Ph.D. students in the U.S. universities. These students are from a very different educational system and cultural background, which may cause challenges in their studies in the U.S. One of these challenges is inadequate English proficiency (Huang, 2004, 2005, & 2006). However, there are little literature concerning the English proficiency of Chinese Ph.D. students in the U.S., let alone doing research on the perception of Chinese Ph.D. students in the biology field. The problem in this study was to explore the perceptions of English language proficiency of Chinese Biology Ph.D. students concerning their lab presentations at a public university in Southern U.S. The research question was: What are Chinese Biology Ph.D. students' perceptions about their English proficiency? The purpose of this study was to inform university graduate school and biology department leaders about their Ph.D. students' needs and weaknesses from students' perspective, so the leaders can design corresponding curriculum in ways that may meet such students' needs and strengthen their weaknesses. In this study, three Chinese biology Ph.D. students were observed and interviewed to examine how they understood their English proficiency and to explore possible links between these understandings and their cultural background and content knowledge. This exploratory study was conducted in a specific U.S. public university but the findings can be useful to a wider audience. The study found that their perception was more relevant to their content-knowledge preparation for presentations and their previous English-learning experiences than cultural influence. These findings suggest that content knowledge and language competence are both important thus should be combined in biology Ph.D. student training programs, in order to improve Ph.D. students' overall English proficiency in their academic life.

129. The examination of the relationship between high school biology experiences, outcome expectations, biology identity, and biology professional choice

Feng Li*, Florida International Univ; Zahra Hazari, Florida International University; Philip Sadler, Harvard-Smithsonian Center for Astrophysics; Gerhard Sonnert, Harvard-Smithsonian Center for Astrophysics

In this study, it is explored how students' biology identity is predicted by their high school biology class experiences and by their future career outcome expectations, as well as how biology identity is related to their choice of a career in biology. Drawing on previous work on identity in education, the framework for this study conceptualizes biology identity as students recognizing themselves as certain "kinds of people". The study utilizes secondary data from the Persistence Research in Science and Engineering (PRiSE) project, which surveyed college English students nationally about their backgrounds, high school science learning experiences, and attitudes in science learning. Multiple regression is employed in this study as the statistical tool to examine the responses of 6,753 students from 40 colleges and universities across the U.S. , This study indicates how strong the students' biology identity indicator is related to their intended choice to pursue a biology career. In order to demonstrate what contributes, either positively or negatively, to biology identity, predictors from students' high school biology experiences and occupational expectations are identified. This study applies a useful theoretical framework based on identity. It also suggests a possible orientation for the reform of high school biology education.

130. Teaching biodiversity positively influences both the cognitive and affective domains

Carol Chaffee*, Iowa State University; Glené Mynhardt, Hanover College; Jim Colbert, Iowa State University

In Fall, 2012, Iowa State University implemented an inquiry-based, discovery-driven approach to the exploration of biodiversity in the first semester of introductory biology. Thus, a primary motivation for this project was to evaluate student attitudes towards and understanding of biodiversity under this new approach. We used surveys of both student attitudes and conceptual understanding to assess how this new approach influenced both the affective and cognitive domains in relation to biodiversity. Surveys of student attitudes were administered both before (Spring, 2012) and after (Fall, 2012, Spring, 2013) the implementation of the discovery-driven approach. Tests assessing biodiversity conceptual knowledge were administered both prior to and immediately following the biodiversity portion of lab in the Spring and Fall, 2013. Our results show that fewer than half of our students enter the introductory biology course believing they have a good knowledge of biodiversity–a result supported by low scores on the conceptual pre-test. While attitudes toward biodiversity showed no significant change during the course, student confidence in their biodiversity knowledge increased significantly (45 percentage points, a 150% increase), and scores on the conceptual post-test indicate this confidence is warranted (13-37 percentage point improvement, 37-300% increases). These results indicate that the inquiry-based, discovery-driven approach significantly improves both the understanding of biodiversity, and student confidence in their knowledge of biodiversity.

131. Student Preconceptions of Genetics Concepts
Anthony Machniak*, Michigan State University; Jennifer Doherty, Michigan State University; Tammy Long, Michigan State University

Biology is a field that places intense cognitive demands on its students. Introductory courses in particular, can be overwhelming for students confronted with the need to master large numbers of concepts and seemingly unrelated facts. To think about biological problems systematically, students must do more than know and recall; they must connect their understanding and think about concepts in relation to one another. For example, the ability to define “gene” is not equivalent to understanding the role of genes in transferring information, predicting traits in organisms, and accounting for genetic change in populations. In this study, we present findings from a pre-course assessment of college students’ genetics knowledge at entry into Bio2. Bio2 is an introductory course that focuses on genetics, evolution, and ecology, and is the second in a 2-course sequence required for life science majors. Bio1 covers cell and molecular biology and is required for Bio2. Our assessment asked students to (a) define and (b) describe the function of each of 7 genetics concepts included in the content of both Bio1 and Bio2: gene, allele, DNA, protein, chromosome, phenotype, and mutation. For our analyses, we developed a grounded rubric that quantified the frequencies of students’ (1) connections with other genetics concepts, and (2) use of specific verbs to describe functions in the context of their responses. Preliminary results (n=60 students) reveal that 37% of associations among genetics concepts relate to phenotypes. While, multiple students reference genes and DNA as leading to individuality and variation among individuals, only one student referenced alleles as causing that variation. Although students often provide adequate definitions, they struggle to connect functions of genetic concepts. These data are relevant in designing appropriate instruction for Bio2 that scaffolds students’ existing knowledge while also addressing conceptual gaps.

132. Undergraduate General Biology Students' Attitudes Towards Biology at a Hispanic-serving University

Seth Manthey*, Florida International Universi; Eric Brewe, Florida International University; Eric von Wettberg, Florida International University; George O'Brien, Florida International University

We present results from our ongoing work to study undergraduate General Biology I at a large, public, Hispanic-serving university. Attitudinal data was collected using the Maryland Biology Expectations Survey (MBEX), which looks at students' attitudes and epistemologies about biology. We use pre- and post-instruction MBEX results to compare two different types of instructional settings: online with a face-to-face laboratory component, and a traditional lecture setting also with a face-to-face laboratory component. The same instructor, using the same materials, taught both sections. Using statistical analysis, we examine the shifts between pre- and post- instruction for both course formats, as well as across course formats. Additionally, we disaggregate the data based on student gender and ethnicity. Our analysis of this attitudinal data provides insight into one aspect important to Biology Education Researchers and science education researchers more broadly. This work also establishes a baseline of data for our future reform efforts of the General Biology course sequence.

133. What does Online Mentorship of Secondary Science Students Look Like?

Claire Hemingway*, National Science Foundation; Catrina Adams, Botanical Society of America

Mentorship plays a strategic role in efforts to engage, recruit and retain science students, yet what mentors do in their roles to support mentees remains largely undocumented. We incorporate frameworks on mentoring, science learning, and online learning research to investigate the nature of mentoring relationships of plant scientists working online with student research teams in an online learning community, www.PlantingScience.org. We ask: How do mentors communicate online with secondary school students to support science investigations? How do scientists perceive their roles as online mentors? We conducted a content analysis of 170 conversations (including 1,086 messages posted by 105 female and 65 male scientist mentors selected in a stratified random sample). We examined responses to survey questions about their motivation for volunteering. We found that mentors employed an array of techniques to broker relationships, help mentees clarify goals, ideas, and procedures, and support reflection on understandings. Acts serving social functions dominated (e.g., affirming, asking about team members' interests, sharing personal information, talking about career pathways and how scientists work). Affirming acts frequently co-occurred with setting expectations, and with eliciting conceptual and procedural ideas. Our results demonstrate how mentors promote the idea of scientific community and welcome students to it, in keeping with their motivations for mentoring. Goodness of fit, Mann-Whitney and Kurskal-Wallis tests revealed differences in discourse patterns according to mentor gender, career stage and level of engagement between teams and mentors. Our findings address research gaps about how scientists negotiate mentoring roles online and integrate multi-dimensional learning goals in dialog with novice science learners.

134. Examining Student Preference for Models vs Narrative Assessments

Etiowo Usoro, Michigan State University; Seth Hunt, Michigan State University; Tammy Long*, Michigan State University

Models and modeling are foundational in the practice and epistemology of biological science and therefore warrant representation in college biology curricula. In an experimental version of introductory biology, we have incorporated conceptual modeling as a way to teach, learn, and assess students' understanding about biological systems. As an assessment, models have potential to reveal more about student thinking than multiple choice and may be more efficient to grade than narrative assessments (e.g., essays). In this study, we examine student preference for these alternative assessment formats. On a case-based midterm exam, students (n=180) were asked to construct both a model and essay that explained how genetic variation originates and is expressed in the context of cystic fibrosis. Prompts for the model and essay were identical and adjacent to one another in the exam, but varied in the order in which they appeared. Students were then asked which (model or essay) they completed first and why. In exams where the model appeared first (n=106 exams), 91% of students completed the model first, suggesting no difference from completing exam items in sequence. However, on exams where the essay appeared first (n=74 exams), a majority (53%) of students also chose to complete the model first, indicating that students were departing from a sequential strategy and actively choosing to answer questions out of order. Overall, students exhibited a strong preference for completing the model first (75% overall; $p < 0.05$) citing that models were "easier" to construct than essays (33%), helped them "organize" (19%) or "visualize" (27%) their thinking, and established the scaffold to "set up" their essays (56%). Our current analyses explore the conceptual content of narratives and essays in order to determine (a) the extent of equivalence between assessment formats, and (b) whether students perform better on their preferred assessment format.

135. The effects of group testing on student performance and retention in a large biology course.

Pamela Kalas*, UBC; James Cooke, UBC; Laura Weir, University of British Columbia; Carol Pollock, UBC; Bridgette Clarkston, UBC

At our institution, an increasing number of science courses have been adopting two-stage exams in which students write an exam individually, followed by writing the same (or similar) exam again in a group. Data from departments of Physics and Earth and Ocean Science (EOS) indicate higher learning gains associated with the collaborative aspect of two-stage exams (Rieger and Heiner, 2014; Gilley and Clarkston, 2014). Because of these reported benefits, and to better reflect the fact that students spend large amounts of class time engaged in collaborative learning and peer teaching, we and others have recently moved to the two-stage format in our large first year biology course. To determine whether the group component of multi-stage exams might increase retention of course material for our biology students, similar to our colleagues in EOS and Physics, we compared test scores of students that wrote material in a group to those who saw the same material individually. The format of the exam questions did not change from the traditional one-stage format and, importantly, consisted of a combination of problems and short answer questions. Learning gains were measured by comparing individual students pre- and post-test scores and calculated as a normalized change. We found that students that wrote group exams scored significantly higher than controls re-writing exam questions individually, and students' perceptions on the group exams were overwhelmingly positive. However, we found that there was no significant effect of group testing on retention of information at both 9 and 23 days after the multi-stage exams, despite a trend to increased retention across all 4 subjects tested. We will discuss our findings and their implications, with comparison to other groups who have obtained similar (Leight et al., 2012) and different (Cortright et al., 2003) results in large biology classrooms in the past.

136. Big classes, big teaching teams, big challenges… some successes! Implementing and evaluating course transformations in first-year biology.

Megan Barker, University of British Columbia; Martha Mullally*, University of British Columbia; Sunita Chowrira, University of British Columbia; Pamela Kalas, UBC; Gulnur Birol, University of British Columbia; Shona Ellis, University of British Columbia

The University of British Columbia has embarked on a campus-wide Flexible Learning initiative with the goal of promoting effective and dramatic improvements in student achievement. In biology, this goal translates into course transformations that emphasize active learning, application, and problem-solving during class, and fact transmission outside of class in a "flipped classroom" model. We have systematically examined the impact of these course transformations on student learning and perceptions, and instructor perspectives. The study took place in two large, multi-section introductory biology courses. Not all course sections participated in implementation, allowing for direct comparison of the initiative's impact. To evaluate effectiveness of the approach, several measures were collected: student scores on validated concept inventories; in-class observations; student perspective and attitude surveys; and teaching team workloads. Further, qualitative observations were collected in the form of teaching team feedback and student comments. Our results demonstrate significant increases in student learning in the transformed versus untransformed sections of the course. Perspective data shows that a strong majority of students value active learning approaches to course instruction, though some activities are viewed as more tightly aligned to assessment. Measurements of TA workload and their feedback highlighted an opportunity to improve post-class activities and TA professional development. Qualitative observations indicate that the two teaching teams had very different challenges in the implementation, and show that the course approach and dynamics of the teaching team involved must inform the implementation of large-scale teaching initiatives. This case is a work-in-progress and of particular interest to instructors and administrators involved in implementation and evaluation of large, multi-section course transformation projects.

137. Content first, jargon second: an assessment of the influence of technical vocabulary on conceptual learning

Megan Barker*, University of British Columbia; Lisa McDonnell, University of British Columbia; Carl Wieman, Stanford University

The University of British Columbia has embarked on a campus-wide Flexible Learning initiative with the goal of promoting effective and dramatic improvements in student achievement. In biology, this goal translates into course transformations that emphasize active learning, application, and problem-solving during class, and fact transmission outside of class in a "flipped classroom" model. We have systematically examined the impact of these course transformations on student learning and perceptions, and instructor perspectives. The study took place in two large, multi-section introductory biology courses. Not all course sections participated in implementation, allowing for direct comparison of the initiative's impact. To evaluate effectiveness of the approach, several measures were collected: student scores on validated concept inventories; in-class observations; student perspective and attitude surveys; and teaching team workloads. Further, qualitative observations were collected in the form of

teaching team feedback and student comments. Our results demonstrate significant increases in student learning in the transformed versus untransformed sections of the course. Perspective data shows that a strong majority of students value active learning approaches to course instruction, though some activities are viewed as more tightly aligned to assessment. Measurements of TA workload and their feedback highlighted an opportunity to improve post-class activities and TA professional development. Qualitative observations indicate that the two teaching teams had very different challenges in the implementation, and show that the course approach and dynamics of the teaching team involved must inform the implementation of large-scale teaching initiatives. This case is a work-in-progress and of particular interest to instructors and administrators involved in implementation and evaluation of large, multi-section course transformation projects.

138. Exploring Ecological Misconceptions among Undergraduate Biology Majors Angelique Troelstrup*, Middle Tennessee State Univ; Katherine Mangione, Middle Tennessee State University

The purpose of this study was to investigate the ecological misconceptions among biology majors at the beginning of an ecology course, but more importantly, which misconceptions they have after taking an in depth course in general ecology. Misconceptions are defined as inaccurate explanations of phenomena constructed by students (D'Avanzo 2003). It isn't that students aren't learning or have a lack of knowledge, instead they have developed incorrect interpretations or alternative conceptions (Munson, 1994). In order to address conceptual change, it is important to understand what happens as a result of instruction in general. A pre and post-test assessment developed by Stamp, Armstrong, & Biger (2006) was given to students in a large lecture ecology course accompanied by simulation and field laboratories. Only students who completed the pre and post survey were included in the final analysis which resulted in a sample of 53 students. The survey consisted of Likert scale items in which students choose strongly agree, agree, don't know, disagree, or strongly disagree between pairs of conceptions and misconceptions. Students revealed several misconceptions at the beginning of the course. Wilcoxon Rank-Sum test revealed that most questions indicated no significant changes from the beginning of the semester compared to the end of the semester indicating instruction alone does not address ecological misconceptions. However, significant differences in some questions indicated a shift from misconception to either conception or don't know or from conception to misconception or don't know. This exploratory study reveals that misconceptions exist amongst biology majors, in depth courses or coursework alone does not address misconceptions, and more thorough assessments may need to be developed to obtain accurate measurements of ecological misconceptions.

139. The influence of peer discussion on the quality of student written explanations
Amanda Banet, University of British Columbia; Laura Weir*, University of British Columbia

Conceptual understanding of a variety of topics in undergraduate biology courses is increased through peer discussion. However, the degree to which peer interaction may help students develop complete and logical written arguments to demonstrate their conceptual understanding is not well known. In this study, we examined the logical content of short written responses to conceptual questions in a large (~500 students), second-year physiology course. Because the course was separated into two sections, we divided it into a control section, in which students individually wrote their answers without peer discussion, and a treatment section, in which students discussed their answers with their peers prior to providing individually written explanations. We repeated this process for 5 questions across a range of topics at different times during the course. To assess student explanations, we constructed a rubric for each question that identified the relevant arguments required in the explanation, as well as common misconceptions or misuse of scientific language. All responses were coded by two individuals with content knowledge, and any discrepancies were discussed to reach a consensus prior to analysis. Our preliminary results suggest that students who engaged in peer discussion prior to providing their written answer were more likely to construct complete responses that contained all arguments necessary to answer the question that was posed. In addition, we identified significantly fewer misconceptions in the responses from students who participated in peer discussion prior to providing their explanation. This study presents a novel approach to assessing the influence of peer discussion to combines conceptual understanding and the communication of that understanding through written explanations.

140. Study Time of Introductory Biology Students by Institution Type

Pamela Pape-Lindstrom*, Everett Community College; Anne Casper , Eastern Michigan University

Students at community colleges, representing about 46% of undergraduates nationwide, are more likely to be from groups historically under-represented in STEM disciplines relative to four year schools. Movement of educational pedagogy towards active learning strategies may increase time demands on students. Consequently, we must be mindful of the greater barriers community college students may experience as they navigate work, school and family commitments. In the present study, community college students, regional comprehensive university students and students at Research 1 universities in the West and Mid-West participated in a time constraints survey. Data analysis shows that community college students spend nearly 40 hours a week working, commuting, and supporting family members, much more than either R1 students (23 h) or students at regional comprehensive universities (26.5 h). Interestingly, students at the R1 schools and the community colleges spend very similar amounts of time studying biology per week (R1= 10.4 h and CC = 10.6 h). And both of these populations spend more time studying biology than students at the regional comprehensive universities. Community college students sacrifice their personal time for study time, as the R1 students spend more time on club activities, relaxing, and sleeping. Further analysis will investigate the impact of low, medium or high course structure on study time, independent of institution type. In summary, community college students are investing as much time studying introductory biology as their peers at R1 institutions, despite spending nearly twice as much time on external obligations. These results indicate that they are up to the challenge of the additional time investment required for active learning strategies.

141. SOLVE: a framework for solving genetics problems.

Terri McElhinny*, Michigan State University

Recent calls for improvement of undergraduate biology education highlight analytical and quantitative reasoning skills as an area of particular concern. Scientific problem solving consists of three basic steps: planning the solution, executing the plan, and checking the solution. In genetics, a discipline that involves complex, multi-step problems, it is also essential that learners keep track of their progress as they work. Expert problem solvers do all of these- plan, execute, monitor, and check for accuracy - automatically. Novice learners can benefit from a structured framework in which to learn these skills. This study describes an intervention designed to address problem-solving deficiencies in undergraduate fundamental genetics students. SOLVE is a 5-step problem-solving framework designed to help genetics students become more metacognitive and thus successful problem-solvers. Students are trained to study the narrative of the question to identify the salient pieces of information, and organize their problem-solving strategy accordingly. Students are then encouraged to check their work during and after completion of the problem to ensure accuracy. To evaluate whether or not students found this framework helpful, I collected student perception survey data from undergraduate students who were trained in the use of the SOLVE framework. Quantitative results suggest that overall, students appreciated learning how to dissect the narrative and plan their problem-solving strategy, but found monitoring their work and checking for accuracy less helpful. Future work will address whether or not students' perceptions of the steps in the SOLVE framework correlate with performance on problem-solving assessments.

142. Evaluating Long-term Outcomes of Introductory Biology Reform: Is STEM Persistence Our Holy Grail?
Tammy Long*, Michigan State University; Jennifer Doherty, Michigan State University; Kristen Kostelnik, ; Diane Ebert-May, Michigan State University

As increasing numbers of faculty adopt learner-centered instructional methods in their courses and programs continue to support these efforts with training and resources, few studies exist that describe the impacts of such interventions beyond the context of the reformed classroom. Of particular interest is the role of reform in maintaining and broadening representation of students in the STEM pipeline. We have concluded a 6-year study that documents patterns of retention and attrition in STEM majors following introductory biology reform. Bio 1 (genetics, ecology, and evolution) is 1 of a 2-course sequence required for life science majors. "Reformed" sections applied learner-centered, evidence-based instructional methods and emphasized engaging students in science practices (e.g., modeling, argumentation, data analysis). "Traditional" sections were taught using lecture-based instruction and emphasized content coverage. We documented the majors declared by students at the time of their enrollment in Bio1, and again at an endpoint defined as graduation or conclusion of Fall 2013 for students still enrolled at the university (i.e., not graduated). Our preliminary analyses indicate statistically different patterns for students from Reformed (n=2286) and Traditional (n=1920) sections of Bio1 ($\chi^2=50.9$, df=2, $p < 0.05$). While rates of retention in STEM majors and conversion from non-STEM to STEM were not substantively different overall, attrition from STEM majors was lower for students from Reformed sections compared to Traditional (7.1% vs. 9.6%, respectively). Patterns are highly variable among demographic groups, but reform appears to have the strongest impacts in improving retention and reducing attrition from STEM majors for African-American and Hispanic students. Our findings suggest that student-centered interventions early in STEM curricula may have the greatest impact in reducing STEM attrition among students from underrepresented groups.

143. Learning Progressions for Ecological Literacy: Helping Student Develop Systems Thinking
Laurel Hartley*, University of Colorado Denver; Jennifer Doherty, Michigan State University; C.W. (Andy) Anderson, Michigan State University; Alan Berkowitz, Cary Institute of Ecosystem Studies; Cornelia Harris, Cary Institute of Ecosystem Studies; John Moore, Colorado State University

We developed a grade 6-14 learning progression, including frameworks and assessments, to describe how students reason about the composition and function of ecological communities. Our work provides recommendations for how to improve student learning and increase their understanding of the links between ecology and evolution. This work is challenging because ecosystems are complex systems governed by a large variety of principles that vary in their importance depending on ecosystem context, and because many students either don't have enough experiences with the natural world to draw from or their experiences are geographically constrained. We administered written assessments to grade 6-14 students (n = 6000) in five states and conducted semi-structured interviews about ecological disturbance scenarios (n=53). We used these assessments to develop a learning progression framework and assess the state of understanding in our sample population. We will present key attributes of our learning progression framework and data illustrating the current state of student understanding of key ideas related to community ecology. We found more advanced students viewed processes as occurring within a nested hierarchy from individuals, to populations, to communities to ecosystems. However, young students did not recognize processes as occurring within a hierarchical, connected system. Instead they reason about the natural world using inappropriate anthropomorphic analogies. These students are able to recognize processes occurring at the level of the individual, but use analogies about family and relationships to discuss ecological communities and use analogies about places and settings to discuss the attributes of ecosystems. Approximately 16% of students exhibited Level 1 (lowest level) reasoning and 3% exhibited Level 4 reasoning. The majority of students reasoned at a Level 2 (54%) or a Level 3 (29%).

144. Evaluating the Efficacy of a Student-Centered Active Learning Environment with Upside-down Pedagogies (SCALE-UP) Classroom for Major and Non-Major Biology Students

Steven Ralph, University of North Dakota; Christopher Felege*, University of North Dakota; Brett Goodwin, University of North Dakota

Pedagogical research has demonstrated that instructor-centered teaching is less effective for student learning than a student-centered environment that promotes active engagement in the construction of knowledge, skills and abilities. Nonetheless, many STEM faculty remain hesitant to transition to an active-learning environment due to concerns about loss of control over content delivery. In fall 2012, the University of North Dakota opened a new SCALE-UP classroom. Here we report a preliminary evaluation of student performance following the transition from an instructor-centered to a learner-centered environment. The study examined two large-enrollment classes: Genetics, a 300-level course required for biology majors; and Concepts of Biology, a 100-level course for non-majors. Prior to the move to SCALE-UP, both classes were taught in a traditional lecture format. In SCALE-UP, classes were redesigned to create a student-centered environment with minimal lecturing and daily use of problem-based learning in student groups. Student performance was assessed using 40 multiple choice questions that were used in both offerings of each course. Questions were categorized by difficulty level according to Bloom's Taxonomy. In addition, student learning of concepts underlying each question was categorized by the pedagogical methods used (e.g., lecture only versus podcast coupled with an in-class activity). Our analysis suggests that empowering students to be responsible on their own for lower-level Bloom's content via assigned reading and/or podcasts, with a concomitant reduction in lecturing, did not negatively impact overall student performance. Furthermore, marked performance differences on individual questions between course offerings could often be traced to specific changes in pedagogical methods. In addition to student performance data, we will also present a summary of student perceptions about learner-centered teaching based on the results of end-of-course surveys.

145. Does Preparation Matter? Adding Reading Quizzes to an Active Learning Class at a Regional Comprehensive University

Anne Casper *, Eastern Michigan University; Sarah Eddy, University of Washington

Active learning improves student success in large-enrollment introductory biology classes at multiple Research 1 universities, yet not much work has been published using this format at other types of institutions. The typical student population at Regional Comprehensive universities is very different from that at R1 institutions, particularly in average student ACT scores and in the size of the minority student population. Therefore, research is needed to determine whether the student population at a Regional Comprehensive university also benefits from implementing active learning in introductory biology, and what modifications are needed to make it successful with this population of students. As many of the students at comprehensive university are first generation, we hypothesize that structuring how students approach the assigned textbook reading through guided reading questions will be critical for student success. In a class of 216 students in Winter 2014, we used a repeated measures design to test this hypothesis where students experienced both treatments (two weeks without guided reading questions and two weeks with guided reading questions). We measured the following three outcomes to document the importance of guided reading questions for both classroom conversations and learning: (a) performance on pre-class quiz questions, (b) in-class responses to clicker questions and (c) performance on weekly post-class practice exams. Results will be discussed.

146. Building a learning progression for chromosome segregation

Stanley Lo*, Northwestern University; Stephanie Kim, Northwestern University; Su Swarat, California State University, Fullerton; Gregory Light, Northwestern University

Learning progressions are descriptions of increasingly sophisticated ways of thinking about a phenomenon. Research in learning progressions moves beyond misconceptions and attempts to characterize the conceptual pathways that students navigate as they learn a concept. This goal of this study is to define a learning progression for chromosome segregation, a critical yet challenging concept. We used variation theory as a theoretical framework. Variation theory posits that each phenomenon (i.e. chromosome segregation) has defined aspects (e.g. recombination), and for each aspect, there is a limited number of features with distinguishable variations among them. Learning occurs when the different features and their variations are integrated into a coherent whole. We interviewed students using a think-aloud protocol to explore their conceptions of chromosome segregation and various aspects related to recombination. Students were asked to solve these problems, while being prompted to explain their thought processes. Data analysis took a grounded approach, with iterative close reading of the interview transcripts to identify features of recombination and variations among them. A major finding is the disconnection among different features that students used to describe chromosome segregation. For example, students with low performance on the exam typically recognized recombination in one of three ways: conceptual, mathematical, or symbolic. Students with increasing performance described the aspect in two or all three features. Additional aspects, e.g. crossing-over, alleles, and homologous chromosomes, are analyzed and will be discussed. We believe that these findings and our approach can shed light on possible ways to build learning progressions for concepts in biology. Defining learning progressions will provide the theoretical foundation to design instructional material that specifically targets transitions along these conceptual pathways.

147. Student approaches to problem solving in genetics

Alexandra Gore, Northwestern University; Stephanie Kim, Northwestern University; Stanley Lo*, Northwestern University

This study is part of a larger project that aims to explore the relationship between conceptual understanding and problem solving. Specifically, the purpose of this study is to investigate the problem solving approaches that students use in biology. We used phenomenography as the framework and methodology. Phenomenography posits that there are a limited number of qualitatively different ways by which people experience, perceive, or conceptualize the same phenomenon, i.e. problem solving in biology. We interviewed students using a semi-structured protocol, in which students were asked to solve three to five problems and were prompted to explain their approaches. Problems were chosen from genetics as the disciplinary context, because genetics involves both quantitative and qualities problems, e.g. recombination and nondisjunction. Data analysis took a grounded approach, with iterative close reading of the interview transcripts to examine approaches that were present across students and problem types. Our data identify three main approaches based on reasoning, algorithms, and test-taking strategies, and each approach can be further subdivided in another dimension along surface and deep. For example, a deep reasoning approach uses reasoning based on concepts in biology and is typically focused on ideas that are relevant to the problem. A surface reasoning approach, while also uses reasoning, tends to be unstructured and attempts to solve the problem in an arbitrary manner. Similarly, students with a deep algorithmic approach utilize algorithms to solve problems, and their algorithms are supported by conceptual understanding. On the other hand, students with a surface algorithmic approach tend to use memorized algorithms detached from biological contexts and meaning. Our results build on similar research in engineering and physics education and identify student approaches to problem solving that are similar and distinct from those in the other disciplines.

148. Comparing student experiences in inquiry-based laboratory courses and research projects in faculty laboratories

John Mordacq, Northwestern University; Andrew Donaldson, Northwestern University; Megan Kalata, Northwestern University; Stanley Lo, Northwestern University

Undergraduate research experience has been linked to increased academic achievement and persistence in biology and is often cited as the rationale for transforming undergraduate laboratory education to include inquiry-based research projects. We hypothesize that engaging in independent research in faculty laboratories is a multifaceted experience that includes but is not limited to inquiry-based projects. To examine how inquiry-based laboratory courses may differ from independent research experiences, we performed a three-way comparison among undergraduates who have taken traditional cookbook laboratory courses, carried out inquiry-based research projects in laboratory courses, and performed independent research in faculty laboratories. We interviewed 30 students, with the interview questions focusing on students' day-to-day experience, perception of learning from the courses or research projects, and sense of community in relation to faculty and other students. Interviews were transcribed verbatim and blinded for analysis. Data analysis took a grounded approach, with iterative close reading of the transcripts to identify common themes relating to student experience, learning, and community. Our results indicate that while research-based laboratory courses can provide students with inquiry experience, they lack the community that research groups may provide. Each faculty research laboratory is community of practice, in which its members share a common goal. On the other hand, laboratory courses, even with research projects, do not necessarily provide the structure for such a community and may not foster the development of students' identity as biologists. While it remains unclear how the different qualities of undergraduate research experience contribute to student outcomes, this study identifies features that could be incorporated into inquiry-based laboratory courses so that they are more similar to independent research experience in faculty laboratories.

150. Training Graduate Teaching Assistants to use active learning in introductory biology labs

Sarah Dalrymple*, University of Tennessee; Elisabeth Schussler, University of Tennessee

In recent years, there has been a nation-wide shift to incorporating inquiry-based labs into introductory biology curricula. Inquiry-based labs typically involve more active learning than traditional verification labs, so they require a different set of teaching skills to implement properly. At many large universities where undergraduate biology curriculum reform has occurred, Graduate Teaching Assistants (GTAs) teach a majority of undergraduate biology labs, but efforts to reform GTA teaching training have often lagged behind curriculum reform. Currently, a consensus on 'best practices' in GTA professional development is lacking, but studies have shown that pedagogical professional development should be ongoing (i.e., rather than a one-time orientation) and be implemented in a way that models desired teaching practices. For our study we reformed the introductory biology GTA training program at a large research institution and measured changes in GTA teaching practices. During the Fall 2013 semester we changed the format of the GTA prep meetings for the introductory Cell Biology and Biodiversity labs to include recurring workshops on active learning that were designed to model best teaching practices. We observed 16 GTAs across both courses at the beginning and end of the semester to measure potential changes in classroom teaching. Since the goal of the workshops was to increase student discussion in the labs, we predicted that the use of student discussion would increase and that lecture would decrease over the course of the semester. However, only the GTAs in the Biodiversity course showed an increase in the amount of time they spent on student discussion. The Cell Biology GTAs, on the other hand, significantly increased the amount of time they lectured when teaching labs. The workshops used for each group were identical, so our results suggest that the different sub-disciplines may require different approaches to GTA training.

151. The effects of introducing active learning strategies on academic achievement in diverse, large-enrollment introductory biology

Binaben Vanmali*, Arizona State University; Christian Wright, Arizona State University; Valerie Stout, Arizona State University; Miles Orchinik, Arizona State University

A large body of research has demonstrated that integration of active and student-centered learning techniques improve student mastery and learning gains. While the assumption is that active learning enhances the achievement and retention of students of diverse backgrounds, we know little about how active learning strategies might differentially affect the performance of highly diverse students in the same classroom. This study focused on two primary questions: 1) How do introductory biology courses that implement structured active learning affect the learning of students of differing performance/abilities (per Colorado Index (CI) score)? and 2) Do courses that employ structured active learning affect retention of students across different groups? These data are essential to advancing an understanding of how to increase student retention. To better understand how active learning impacts students of different academic abilities, we examined the effect of student-centered learning on first semester, introductory biology students taking the molecular genetic component of an introductory biology course at a large, diverse, research-intensive university. Using metrics of student performance, we first determined how active learning courses impact student learning relative to more traditional, lecture based courses. Then, using mixed effects models to account for the impact of individual students on learning gains, we determined the extent to which learning gains on the Genetics Concept Assessment and retention varied across different groups in a student-centered classroom. Here we report our findings and discuss the broader implications for instructional and curricular reform efforts.

152. Can a flipped-classroom approach in combination with inquiry-based learning foster content acquisition and hypothesis testing in introductory biochemistry?

Isabelle Barrette-Ng*, University of Calgary

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. 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 this combination of activities fosters both the acquisition of content and the development of scientific inquiry skills.

153. Students' evolving perceptions about primary literature after taking a course that focuses on analysis and evaluation of scientific articles

Christopher Abdullah*, UCSD; Richard Lie, UCSD; Julian Parris, ; Ella Tour, uCSD

Calls for increased incorporation of original scientific literature into science education (Vision and Change 2009) have led us to develop a Master's level course, part of our contiguous Master's program, that utilizes structured analysis of primary literature to develop Bloom's

Higher Order Cognitive Skills (HOCS) (analysis, evaluation, and synthesis). Since these students are our own recent undergraduates, they provide us with a unique insight into their prior exposure to reading primary literature. We were also interested in what aspects of primary literature they find most difficult, as well as if these perceptions change as a result of the course. To address these questions, we administered an anonymous, online pre- and post-course survey over two quarters. Students' responses suggest limited exposure to primary literature, with 69% of the students reporting having read 0-20 scientific papers before this class. Undergraduate courses and independent reading were the most frequent ways that students were exposed to scientific papers, but only 7% responded that they have been explicitly trained to read papers. These data suggest a need for this type of training in the undergraduate curriculum of our large research-oriented university. We utilized the grounded theory method to categorize students' responses about the most challenging aspects of primary literature and compared the pre- and post-course responses to observe shifts in students' perceptions. Pre-survey responses indicated that understanding experimental techniques (17% of responses), scientific language/writing style (11%), and unfamiliar background (9%) were the most difficult aspects. Students' responses in the post-course survey included decreases in unfamiliar techniques (2-fold) and increases in drawing their own conclusions (7-fold) and evaluating author's conclusions (2-fold). Over the character limit, but within word limit. Please see Word file attached

154. Beyond the content: improving student problem-solving in genetics
Lisa McDonnell*, University of British Columbia; Martha Mullally, University of British Columbia

Problem solving skills are highly valued, however it is uncommon for these skills to be explicitly taught and assessed within our undergraduate genetics courses. Using data from think-aloud interviews and written-answer responses we determined that most students in a 200-level genetics course did not demonstrate the use of problem solving strategies that were used, automatically, by experts. Most striking was that 60-65% of students omitted checking their work, a process which was always observed to be used by experts while solving problems. Students that demonstrated "work checking" were more often successful at solving the problem than students who did not demonstrate checking (chi-square test, $p < 0.01$, $n=57$, written response answers). Based on these results we aimed to determine if integration of problem solving into the course curriculum affected the frequency of students using expert-like problem solving behaviours such as hypothesis formation, application of hypothesis to solve, and checking work. To do this, we treated an entire course section, for an entire term, as a treatment group which received explicit instruction on problem solving (in the context of genetics problems) and formative and summative assessment on checking of their work, and compared their use of problem solving behaviour to that of students from a control group (no problem solving taught or assessed). Think aloud interviews of a subset of students from the treatment ($n=10$, 15% of class) and control ($n=24$, 12% of class) showed that students from the treatment group demonstrated work-checking at a higher frequency than students from the control group (Tukey's post-hoc test $p < 0.001$), particularly when solving challenging problems. Results of this study contribute to our understanding of student problem solving, point to the value of teaching context-specific problem solving, and have implications for the incorporation and assessment of skills-based goals.

155. Longitudinal Study of Student Attitudes in a Biology Program
Malin Hansen*, University of British Columbia; Gulnur Birol, University of British Columbia

Pre-held attitudes such as interests, beliefs, confidence and self-efficacy, may impact how students approach learning (e.g. effort, problem-solving strategy, study habits, and critical thinking) within that discipline. In order to facilitate learning, it is therefore important that educators familiarize themselves with student attitudes and associated behavior (i.e., approach towards learning) as well as the factors that may influence these attitudes. Our study is among the first longitudinal studies to report student attitudes over four years of a university program. Using a validated attitudinal survey (the CLASS-Bio), we found that the attitudes of students in biology become significantly more expert-like from the 1st year to the 4th year of the program, i.e., there was a significant positive shift in students' overall % favourable scores from 64.5% to 72%, as opposed to the expert response averaging 90%. There was a significant positive shift for the real world connection category (78% to 85%), the enjoyment (personal interest) category (74% to 82%), and the conceptual connections/memorization category (66% to 74%). However, our results also show that about 50% of the students find it difficult to apply concepts to solve problems in biology and to explain answers to questions in their own words. Should we expect students' confidence and effort in problem solving to be higher than this after four years in a university program? We encourage science educators to consider this question when designing courses and programs and to set goals for their students both in terms of student achievement as well as attitudes and confidence.

156. Bait and switch: Effect of changing cognitive level of assessment items on student performance
Erika Offerdahl*, North Dakota State University; Jessie Arneson, North Dakota State University

Within the life sciences, Bloom's Taxonomy of Educational Objectives has been widely used as to classify assessment items, particularly within the context of research on student learning. As a hierarchy of cognitive skills, Bloom's taxonomy represents a progression from simple to complex cognitive skills, concrete to abstract thinking. It has largely been assumed that students will more frequently perform better on assessment items at the lower levels of Bloom's taxonomy – that they are "easier" than items at higher levels. Recent studies have demonstrated that while cognitive level may contribute to student performance on assessment items, the actual amount is unclear. The purpose of this study was to examine the relationship between Bloom's level and student performance on classroom assessment items. We tested the hypothesis that students with demonstrated success on items assessing HOCS will demonstrate similar levels of success on items assessing LOCS. We collected all graded classroom assessments (15 online progress checks, 6 quizzes, and 3 exams) in a large-lecture upper-level biochemistry course (N=295). Each assessment item was assigned a Bloom's level by at least two independent raters with >90% agreement. Student performance data were also recorded for each item. Lecture notes and in-class activities used to determine the degree to which HOCS were scaffolded prior to each quiz and exam. Our data showed that in the first two-thirds of the course, HOCS were routinely assessed whereas the final third of the course assessed predominantly LOCS. 33% of students performing well on HOCS assessments (>80% correct) performed significantly lower on LOCS assessments. Analysis of classroom instruction suggest that poor performance might be due to misalignment between skills routinely practiced in class (HOCS) compared to those assessed (LOCS).

157. Virtual Teams: Failures and Successes in a Blended General Education Course
David Gross*, University of Massachusetts

Teamwork is a successful component of the active learning classroom, most commonly employed in a face-to-face setting. We have postulated that virtual teams, formed and delivered outside of class via an online learning management system, will provide aspects of the active learning team environment similar to that offered in class. Our findings suggest that under some specific conditions this hypothesis is validated, but under other circumstances it is not. A general education course in human genetics and molecular biology, Biochem 100, My DNA, was converted from a standard face-to-face lecture course to a blended course and was studied over a three-year period. Compared to the lecture course, the blended course had half of the face-to-face time with the instructor (75 minutes, once per week) supplemented with more than 75 minutes of online prerecorded lectures, online homework, and online team activities. The online team activities were composed of five projects of varied content concurrent with course topics and peer-peer review. Two modes of team formation were examined: random teams of 5 members and self-selected teams of from 1 to 5 members. The latter were optional in the sense that students were not forced to work with others but did have the opportunity to do so. We adopted this format in year 3 of our study in response to a student attitude survey that indicated that the random teams did not function well. Nearly half of the random teams had one or more dysfunctional members who either did not correspond with other team members or who were uncooperative. In contrast, nearly all of the self-formed teams functioned well. Student attitudes toward virtual team activities were consistent with student participation in self-formed teams.

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