14th Annual SABER National Meeting
Conference Materials

Conference Dates
July 11 – 14, 2024

University of Minnesota
Minneapolis, Minnesota
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# SABER National Meeting Schedule

**Thursday, July 11, 2024**

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<thead>
<tr>
<th>Time</th>
<th>Pre-Conference Workshops</th>
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| 9:00 AM – 12:00 PM | **How to integrate science communication into your biology course using active learning.**  
Mark A. Sarvary (Cornell University)*; Kitty Gifford (Cornell University) | **Developing No-Code, AI-Enhanced, Online Study Tools for Biology Students: A Beginner’s Workshop**  
Keefe Reuther (UC San Diego)*; Liam O Mueller (UC San Diego); Grace Constantian (UC San Diego); Albert Nguyen (UC San Diego) | **Crossing Boundaries: Uniting Math and Biology Through Modeling**  
Kristine Squillace Stenlund (UMN)*; Anita Schuchardt (University of Minnesota) | **Structural Equation Modeling: Using JASP as a Companion to R.**  
Ashli M Wright (Florida International University)*; Alexander Eden (Florida International University) |
| 3:30 PM – 5:00 PM  | **Welcome by SABER President Kelsey Metzger**                                              |
|                    | **Keynote Address: Dr. Chandralekha Singh**                                               |
|                    | Distinguished Professor of Physics in the Department of Physics and Astronomy and the Founding Director of the Discipline-based Science Education Research Center (dB-SERC) at the University of Pittsburgh |
| 5:15 PM – 6:15 PM  | **Mentoring Group Meetings**                                                               |
| 6:30 PM – 8:00 PM  | **Poster Session and Social Hour**                                                         |
## Concurrent Short Talks – Session 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 1_A</th>
<th>Session 1_B</th>
<th>Session 1_C</th>
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| 8:30 – 8:50 AM | **How to Write Your CourseSource Manuscript: Outcomes and Lessons Learned From Five Years of Writing Studio Workshops.**  
Sharleen Flowers (University of Colorado, Boulder)*; Zachary Hazlett (University of Colorado, Boulder); Marie Ramirez (Cornell University); Kira Treibergs (Cornell University); Erin Vinson (Codon Learning); Michelle Smith (Cornell University); Jenny Knight (University of Colorado, Boulder) | **DisCrit and BER: A Theoretical Case Study for Methodological Shifts in Biology Education Research.**  
Mariel Pfeifer (University of Mississippi)*; Ariel J Chasen (UT Austin)                                                                 | **Characterizing Students’ Epistemic Networks for Reasoning about Natural Selection.**  
Julia Gouvea (Tufts University)*; Sugat Dabholkar (Tufts University); Scott Benjamin (Bunker Hill Community College); Sukanya Chakraborty (Florida State University) |
| 8:55 – 9:15 AM | **Understanding biology undergraduates’ mentoring experiences at a Hispanic-Serving Institution and their effect on student career development.**  
Hector G Loyola Irizarry (Florida International University)*; Krista Donis (Florida International University); Roxana Gonzalez (University at Buffalo); Mia Uzcategui (Florida International University); Rocio Benabentos | **Can an interdisciplinary and inter-institutional Community of Transformation promote collaboration and STEM education reform? Yes!**  
Ethan X Roberts (California State University, Sacramento)*; Catherine Ishikawa (California State University, Sacramento); Kelly McDonald (California State University, Sacramento) | **Are they cousins? Exploring student acceptance of common ancestry in evolution.**  
Taya Misheva (Syracuse University)*; Jason Wiles (Syracuse University) |
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<th>Time</th>
<th>Session Title</th>
<th>Authors</th>
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<tr>
<td>9:20</td>
<td><strong>Moving more students from STEM degree to STEM workforce: is targeted career development the key?</strong></td>
<td>Melissa McCartney (University at Buffalo)*; Roxana Gonzalez (University at Buffalo); Mia Uzcategui (Florida International University); Jessica Liberles (Florida International University)</td>
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<td>9:45</td>
<td><strong>Investigating Career and Research Experience Access Through Evidence (iCREATE) at a Hispanic-Serving Institution.</strong></td>
<td>Roxana Gonzalez (University at Buffalo)*; Hector G Loyola Irizarry (Florida International University); Mia Uzcategui (Florida International University); Wensong Wu (Florida International University); Rocio Benabentos (Florida International University); Jessica Liberles (Florida International University); Melissa McCartney (University at Buffalo)</td>
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<td><strong>Development and Validation of the Team Member Perceptions of Instructional Change Collaborations (TM-PICC) Survey.</strong></td>
<td>Amreen Thompson, Alice Olmstead, Madison Fitzgerald-Russell, Diana Sachmpazidi, Cynthia Luxford, Andrea Beach, Charles Henderson.</td>
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<td><strong>Undergraduate Life Science Professors’ Perception of the Vision and Change Core Content and Competencies for Preparing Students for Science Careers.</strong></td>
<td>Ashli M Wright (Florida International University)*; Melissa McCartney (University at Buffalo)</td>
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<td><strong>Can non-religious instructors decrease perceived conflict between religion and evolution? A randomized controlled study.</strong></td>
<td>Elizabeth Barnes (Middle Tennessee State University)*; Rahmi Q Aini (Middle Tennessee State University); Baylee A Edwards (Arizona State University)</td>
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<tr>
<td>Time</td>
<td>Concurrent Roundtable Sessions</td>
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<td>10:30 – 11:25 AM</td>
<td><strong>Roundtable 1: Exploring the Impact of Collaborative Educational Models on Biology Undergraduate and Faculty Development</strong>&lt;br&gt;Kristine L Callis-Duehl (Donald Danforth Plant Science Center)*; Precious Hardy (Donald Danforth Plant Science Center)</td>
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<td><strong>Roundtable 2: Preparing Underrepresented Students: Employing the Power of Undergraduate Research to Generate Motivation for Successful STEM Students</strong>&lt;br&gt;Matthew Blank (Baylor College of Medicine)*; Curtis Henderson (Houston Christian University); Illya Medina Velo (Houston Christian University)</td>
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<td><strong>Roundtable 3: Teaching Experimental Design in Undergraduate Introductory Biology for Transfer of Learning to Scientific Literacy</strong>&lt;br&gt;James Cerven (Dominican University); Christopher Anderson (Dominican University); Carissa Buber (Dominican University); Scott A Kreher (Dominican University)*</td>
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<td><strong>Roundtable 4: Improving teamwork in undergraduate research-based courses: Tools from team science</strong>&lt;br&gt;Heather D. Vance-Chalcraft (East Carolina University)*; Fiona Freeland (East Carolina University)</td>
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<td><strong>Roundtable 5: Exploring the Impact of CUREs on Pre-Service Elementary Teachers: Science Affinity, Motivated Learning Strategies, and Perceptions of Instructional Support</strong>&lt;br&gt;Amandeep Kaur (Texas State University)*; Carrie Bucklin (Texas State University); Kristy Daniel (Texas State University); Sunni Taylor (Texas State University)</td>
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<td><strong>Roundtable 6: Preparing Community College Transfers for Graduate School: Graduate Faculty Perspectives on CURES as Research Experience</strong>&lt;br&gt;John Espinosa (UC Merced)*; Marcos García-Ojeda (University of California, Merced)</td>
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<td><strong>Roundtable 7: Curriculum Reform that Fosters Equity and Inclusion</strong>&lt;br&gt;Anastasia Chouvalova (Texas Tech University); Adriel Cruz (Sierra College); Nicole Scheuermann (Northern Illinois University); Ariel Chasen (University of Texas Austin); Dawn Foster-Hartnett (University of Minnesota Twin Cities); Cathy Ishikawa (California State University)</td>
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Sacramento); Brock Couch (Loyola University of Maryland); Ashli Wright (The Ohio State University); Erika L Williams (North Carolina Agricultural and Technical State University); Justine S Liepkalns (Colorado State University); Bailey Von der Mehden (University of Tennessee Knoxville); Andrea Schnitz (Southwestern College); Amanda G Conner (Georgia Southern University); Beverly Smith-Keiling (University of Minnesota Twin Cities); Clark R Coffman (Iowa State University)*; Mike Klymkowsky (University of Colorado Boulder); Teri Balser (University of Calgary)

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<td>11:30 AM – 12:00 PM</td>
<td>Business Meetings: PEER Committee, Website Committee, Development Committee, Diversity and Inclusion Committee, DASC Committee</td>
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<td>DBER-SiT Graduate Student and Postdoc Welcome Meeting</td>
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<td>12:05 – 12:35 PM</td>
<td>SIG Meetings: Community College and Biology Education Research, Immunology Education, LGBTQ+, Physiologists, Teaching-focused Faculty in BER, Generative AI</td>
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<td>12:40 – 1:10 PM</td>
<td>SIG Meetings: Community College and Biology Education Research, Immunology Education, LGBTQ+, Physiologists, Teaching-focused Faculty in BER, Generative AI PEER Group Meeting with Dr. Chandralekha Singh</td>
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<tr>
<td>1:15 – 1:45 PM</td>
<td>Vender Workshops: Codon Learning, McGraw Hill, Norton, SimBio, DataClassroom DBER SiT Meeting with Dr. Chandralekha Singh</td>
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### Concurrent Short Talks – Session 2

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<td>What student struggles do instructors see? Teacher noticing in course-based undergraduate research experiences. Alexandra Cooper (University of Georgia)*; Marie Delcy (University of Georgia); Erin Dolan (University of Georgia)</td>
<td>Fostering Meaningful Research: Examining How Students Connect to Broader Contexts in CUREs. Lily R Dodge (University of Minnesota); Dhanya Attipetty (University of Minnesota)*; Catherine Kirkpatrick (University of Minnesota); Anita Schuchardt (University of Minnesota)</td>
<td>Insights from Year 1 and Year 2 of The College Learning Study: How Life Science Students’ Metacognitive Regulation Skills Change Over Time. Stephanie M Halmo (University of Georgia)*; Olive McKay (University of Georgia); Brandon Reece (University of Georgia); Rayna Carter (University of Georgia); Gheed Nafea (University of Georgia); Julie Dangremond Stanton (University of Georgia)</td>
<td>Does a science-practice based laboratory curriculum impact students’ science self-efficacy, science identity and science community values? A randomized controlled study. Shane A Thomas (Washington State University)*; Susan Hester (University of Arizona); Shavindi Ediriarachchi (University of Georgia); Molly S Bolger (University of Georgia)</td>
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<td>2:25 – 2:45 PM</td>
<td>Development of Learning Outcomes for Non-Major Introductory Biology Using a Delphi Method. Peggy Brickman (University of Georgia)*; Cara L Gormally (Gallaudet University)</td>
<td>Investigating student noticing of quantitative reasoning in introductory biology labs. Jeremy Hsu (Chapman University)*; Sara Gartland (University of Delaware); Joelle Prate (Chapman University); Charles Hohensee (University of Delaware)</td>
<td>Exploring STEM GTAs’ Perceptions of Teaching Autonomy, Pedagogical Discontentment and Self Efficacy. Alyssa Freeman (Idaho State University)*; Grant E Gardner (Middle Tennessee State University); Marco Said (Middle Tennessee State University); Beari Jangir (Middle Tennessee State University); Chelsea Rolle (Middle Tennessee State University); Kadence Riggs (Middle Tennessee State University)</td>
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<p>| 2:50 – 3:10 PM | How Administration Stakes Impact Student Behaviors During Concept Assessments. Tiffany Burgess (University of Nebraska-Lincoln)<em>; Crystal Uminski (Rochester Institute of Technology); Brian Couch (University of Nebraska-Lincoln) | Participation in primary literature critique opens opportunities for undergraduate biology majors’ recognition of themselves as epistemic agents. Gabrielle Jablonski; Anna Grinath (Idaho State University)</em> | Testing mindset interventions at two levels improved student outcomes at a Historically Black University. Anisha Navlekar (Texas Tech University)<em>; Adreinne Smith (North Carolina Agricultural and Technical State University); Elizabeth A. Canning (Washington State University); Anastasia Chouvalova (Texas Tech University); Kimberly Pigford (North Carolina Agricultural and Technical State University) | Core Stages of Graduate Education Activate Imposter Syndrome for Biology Doctoral Students. Ariel Steele (University of Minnesota)</em>; Grace-Divine L Boutouli (University of Minnesota); Lydia Swanson (University of Minnesota); Joshua Reid (Texas Tech University); A. Kelly Lane (University of Minnesota Twin Cities) |</p>
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<th>Time</th>
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<td>3:15 – 3:35 PM</td>
<td>Exploring Tones, Trends, and Tales in the Syllabi of Undergraduate Biology Courses.</td>
<td>Ania Majewska (The University of Georgia)*; Areeb Khan (The University of Georgia); Robert Richards (Georgia Tech); Chioma Anyanwoke (The University of Georgia)</td>
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<td>Lab Talk: Does non-content instructor talk explain effectiveness of CUREs?</td>
<td>C.J. Zajic (University of Georgia)*; Jeffrey T. Olimpo (The University of Texas at El Paso); Kelly Subramanian (UC Davis); Benjamin Listyg (University of Georgia); Erin Dolan (University of Georgia)</td>
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<td>Factors that influence academic help-seeking in undergraduate biology courses: a social ecological perspective.</td>
<td>Sharday N Ewell (University of Mississippi)*; Ryan D.P. Dunk (Auburn University); Jordan Fluker (Auburn University); Alayna Harvey (Auburn University); Amelia Radocha (Colorado College); Rachel M Youngblood (Auburn University); Audrey C Lew (University of California, Irvine); Shobnom Ferdous (Auburn University); Yohannes Mehari (Auburn University); Ashley Peart (Auburn University); Michael Seibenhener (Auburn University); Cissy Ballen (Auburn University)</td>
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<td>The effect of exclusionary curriculum on LGBTQ+ students’ sense of belonging.</td>
<td>Ryan D.P. Dunk (Auburn University)*; Dax Ovid (University of Georgia); Joshua Reid (Texas Tech University); Jeremiah Henning (University of South Alabama); Cissy Ballen (Auburn University)</td>
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<td>3:40 – 4:10 PM</td>
<td><strong>Make it personal:</strong> Individualizing post-exam encouragement increases future exam scores for undergraduate genetics students. Hannah Jordt (University of Washington)<em>; Quila Welch (University of Washington)</em>;</td>
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<td><strong>What do you remember from first year biology? An investigation of student knowledge retention using two-stage examinations.</strong> Cassandra Debets (University of Manitoba)*; Abby Judge (University of Manitoba); Kevin G.E Scott (University of Manitoba)</td>
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<td><strong>Understanding curricular influences on students’ science confidence and science identities during an introductory biology laboratory course.</strong> Susan Hester (University of Arizona)*; Shane A Thomas (Washington State University); Sophia Holguin (University of Arizona); Jessica Lumm (University of Arizona); Molly S Bolger (University of Georgia)</td>
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<td><strong>Finding Your True North: A purpose-driven approach to developing students’ STEM career self-efficacy, identity and sense of belonging.</strong> Shahnaz Masani (Michigan State University)*; Rhian Soloman (Michigan State University); Lauren Lambert (Michigan State University); Haiden Perkins (Arizona State University); Krysta Foster (Michigan State University)</td>
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<td><strong>BREAK</strong></td>
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<td>4:15 – 5:15 PM</td>
<td><strong>Long Talk: Investigations into undergraduate students’ experiences of scientific failure and the impact of identity on perceptions of failure.</strong> Sandhya Krishnan (University of Colorado Boulder)<em>; Jason Corwin (University of Colorado Boulder); Joseph Harsh (James Madison University); Isabel Cobb (James Madison University); Lisa A Corwin (University of Colorado Boulder)</em></td>
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<td><strong>BREAK</strong></td>
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<td>6:00 – 7:30 PM</td>
<td><strong>Poster Session and Social Hour</strong></td>
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<td>7:30 PM</td>
<td><strong>SIG Dinners</strong></td>
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<td><strong>DBER SiT Graduate Student and Postdoc Social</strong></td>
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### Saturday, July 13, 2024

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<th>Time</th>
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<tr>
<td>8:30 – 9:30 AM</td>
<td><strong>Keynote Address: Justice Jones</strong></td>
<td>Artist, educator, and organizer at Community Members for Environmental Justice and Powderhorn Park Neighborhood Association</td>
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<td>9:30 – 10:00 AM</td>
<td>Coffee Break sponsored by College Board</td>
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<td><strong>Concurrent Short Talks – Session 3</strong></td>
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<td><strong>Session 3_A</strong></td>
<td><strong>Session 3_B</strong></td>
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<tr>
<td>10:00 – 10:20 AM</td>
<td>The Mentoring Experiences in Research &amp; Graduation Education (MERGE) survey: A robust tool for measuring graduate students’ negative mentoring experiences.</td>
<td>Math Meets Biology: Analyzing Undergraduate Biology Students’ Sensemaking in Hardy-Weinberg Equilibrium and Inheritance Written Problems.</td>
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<td>Trevor T Tuma (University of Georgia)*; John David Adams (University of Georgia); Jenny Choi (University of Georgia); Erin Dolan (University of Georgia)</td>
<td>Amber G Armstrong (University of Minnesota)*; Desi Desi(University of Minnesota); Michael Fleming (CSU Stanislaus); Kevin Haudek (Michigan State University); Anita Schuchardt (University of Minnesota)</td>
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<td><strong>Session 3_C</strong></td>
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<td>A Power of Place Learning Experience and Research Network (APPLE R Net) to Support Community College Scientific Civic Engagement.</td>
<td>A Breadth Course Model Fostering Equitable Science Connection through Challenge-Based Learning.</td>
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<td>Deidre Jaeger (University of Colorado Boulder)*; Amy K. Dunbar-Wallis (University of Colorado, Boulder); Teresa Bilinski (University of Colorado Boulder); Maggie Prater (Front Range Community College); Laura K Baumgartner (Front Range Community College); Laura K Baumgartner (Front Range Community College); Paige Littman (University of Colorado Boulder); Paul Le</td>
<td>Haider Ali Bhatti (University of California, Berkeley)*</td>
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<td>Time</td>
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<tr>
<td>10:25 – 10:45 AM</td>
<td>Experiences of Christian and Muslim students during peer interactions in their undergraduate biology courses.</td>
<td>Baylee A Edwards (Arizona State University)*; Sara Brownell (Arizona State University)</td>
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<tr>
<td>10:50 – 11:10 AM</td>
<td>Why have peer mentors? Undergraduate STEM students’ perspectives on the nature and outcomes of traditional and peer mentors.</td>
<td>Krista Donis (Florida International University )*; Sarah L Eddy (University of Minnesota)</td>
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<td>Investigating the role of students’ achievement goals on their use of ChatGPT.</td>
<td>Julia Mellary (University of Guelph)*; Rayan Kanaan (University of Guelph); Nathan Cozzi (University of Guelph); Tim Bartley (University of Guelph); Dan Grunspan (University of Guelph)</td>
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<td>11:15 – 11:35 AM</td>
<td>PEER students and faculty research mentors view benevolence differently in the relationship. Star Lee (University of California, Irvine)*; Haley Miyasato (University of California, Irvine); Jocelyn Tirado (University of California, Irvine); Stephanie Dingwall (University of California, Riverside); Richard Cardullo (University of California, Riverside)</td>
<td>Graphing Under the Microscope: Examining Undergraduates’ Graph Knowledge in Introductory Biology Courses. Nouran E Amin (Purdue University)*; Kal Holder (Purdue University); Eli Meir (SimBio); Susan Maruca (SimBio); Joel Abraham (CSU Fullerton); Stephanie M Gardner (Purdue University)</td>
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<td>11:40 AM – 12:00 PM</td>
<td>- The impact of research, teaching, mentoring, and service on science faculty depression.</td>
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<td>Katelyn M Cooper (Arizona State University)*; Tasneem F Mohammed (ASU); Sara E Brownell (Arizona State University)</td>
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<td>- Model Provision Versus Model Creation: Impacts on Student Reasoning about Ecosystem Carbon Cycling.</td>
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<td>Seth W Hunt (Michigan State University)*; Tammy M Long (Michigan State University)</td>
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<td>- Experimental design skills can be improved using modular guided inquiry activities.</td>
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<td>Justin Fendos (Xian Jiaotong Liverpool University)*</td>
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<td>- Impact of Specifications Grading on Student Voice, Performance and Learning Strategies in Introductory Biology Classes.</td>
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<td>Min Zhong (Auburn University)* &amp; Jianwei Dong</td>
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<tr>
<td>11:45 AM</td>
<td>Lunch</td>
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<td>12:00 – 12:30 PM</td>
<td>DBER SiT meeting with Justice Jones</td>
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<td>12:30 – 1:00 PM</td>
<td>Concurrent Vendor Workshops: Codon Learning, Norton, SimBio, Data Classroom, PEER Group Meeting with Justice Jones</td>
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<td>Concurrent Roundtables</td>
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| **Roundtable 8:** The Interplay of Social Capital and Field Education: Influences on Student Emotional Outcomes  
  Annie E Meeder (University of Colorado Boulder)*; Lisa Corwin (University of Colorado Boulder) |
| **Roundtable 9:** Strategies for Building a DBER Cluster at a University  
  Click here to add to My Schedule.  
  Peggy Brickman (University of Georgia)*; Paula P. Lemons (University of Georgia); Erin Dolan (University of Georgia); Tessa C Andrews (University of Georgia) |
| **Roundtable 10:** Investigating a framework integrating ideas from inclusive teaching and classroom communities of science practice for supporting students’ sense of science belonging in a large-enrollment introductory biology class  
  Susan Hester (University of Arizona)*; Lisa Rezende (University of Arizona)*; Corin Gray (University of Arizona)* |
| **Roundtable 11:** Navigating the Minefield: Impact and Implications of Anti-DEI Measures  
  Erika L Williams (North Carolina Agricultural and Technical State University); Nicole L Scheuermann (Northern Illinois University)*; Brock Couch (Loyola University, Maryland); Justine S Liepkalns (Colorado State University); Bailey M Von der Mehden (University of Tennessee, Knoxville); Clark R Coffman (Iowa State University); Ariel J Chasen (UT Austin); Teri Balser (University of Calgary); Dawn Foster-Hartnett (University of Minnesota) |
| **Roundtable 12:** "The Intersection of Chance Events, Chronic Illness, and Graduate Student Career Trajectories"  
  Hope Ferguson (University of Tennessee)* |
| **Roundtable 13:** Investigating how field courses held at field stations effect self-efficacy and sense of belonging in biology undergraduate students  
  Zachary Schwartz (University of Colorado, |
Boulder); Lisa A Corwin (University of Colorado Boulder)

University; Sharday N Ewell (University of Mississippi); Dawn Foster-Hartnett (University of Minnesota); Marcos García-Ojeda (University of California, Merced); Kristen Hobbs (Kansas State University); Kristina K Prescott (University of Minnesota, Twin Cities); Kent Reed (University of Minnesota); Lecia Robinson (Tuskegee University); Preston Robinson (Tuskegee University); Archana Sharma (Tuskegee University); Deena Wassenberg (University of Minnesota); Sehoya Cotner (University of Bergen)
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<td><strong>2:10 – 2:30 PM</strong></td>
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### Sunday, July 14, 2024

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<th>Time</th>
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<tr>
<td>7:30 – 8:20 AM</td>
<td>PEER/DEI/LGBTQ+ Coffee and Informal Gathering</td>
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<tr>
<td>8:00 – 8:30 AM</td>
<td>DBER SiT meeting with Dr. Sandhya Krishnan and Dr. Lisa Corwin</td>
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<td>8:30 – 9:30 AM</td>
<td>SABER Business Meeting and Awards Presentation</td>
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<td>9:45 – 10:05 AM</td>
<td><strong>Current Short Talks – Session 5</strong></td>
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<td><strong>Session 5_A</strong></td>
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<td>Exploring how feature of the course environment influence student engagement in STEM active learning courses: A Control-Value Theory approach. Yoon Ha Choi (Digital Promise); Elli Theobold (University of Washington); Sarah L Eddy (University of Minnesota)*</td>
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<td><strong>Session 5_B</strong></td>
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<td>Testing three interventions to mitigate test anxiety and improve performance and retention in Norwegian STEM higher education. Ruben Thormodsæter (University of Bergen); Sehoya Cotner (University of Minnesota)*</td>
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<td><strong>Session 5_C</strong></td>
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<td>Exploring the costs of undergraduate research for low-income students. Emma C Goodwin (Arizona State University)*; Sailor Dereadt (Arizona State University); Jasmine Goode (Arizona State University); Bec Kalfus (Arizona State University); Gailan Khanania (Arizona State University); Laura Pang (Arizona State University); Sara Brownell (Arizona State University)</td>
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<td><strong>Session 5_D</strong></td>
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<td>Navigating across the DNA Landscape: Student sketches reveal molecular biology misunderstandings related to scale and abstraction. Crystal Umsinski (Rochester Institute of Technology)*; Dina Newman (Rochester Institute of Technology); Kate Wright (Rochester Institute of Technology)</td>
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<td>10:10 –</td>
<td>Perceptions of interdisciplinary critical thinking among biology and physics undergraduates.</td>
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<td>10:30 AM</td>
<td>Using a QuantCrit approach to develop and collect evidence of validity for a measure of Community Cultural Wealth.</td>
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<td>Bridging the Gap: Enhancing Research Lab Access Through Early Academic Pathway Intervention.</td>
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<td>Analyzing Undergraduate Student Experimental Design Using a Card Sorting Tool.</td>
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<td>10:35 –</td>
<td>The Value of Support: STEM Intervention Programs Impact Student Persistence and Belonging.</td>
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<td>Comparing performance-based assessments of graph construction across biology subdisciplines.</td>
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<td>Defining and Measuring College STEM Student Trust in Their Instructor Using a Process Model Approach.</td>
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<td>11:00 – 11:20 AM</td>
<td><strong>Examining the Exclusionary and Affirming Peer Interactions of Racially Minoritized Students in Active Learning Science Classrooms.</strong> Hannah Nichols* (University of Georgia); Jordan Roberts (University of Georgia); Renette-Kaire Fopa Tchocksi (University of Georgia); Matthew Turnipseed (University of Georgia); Chase Anderson (University of Georgia); Tatiane Russo-Tait (University of Georgia)</td>
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<td><strong>Reading-to-learn scientific papers improves argumentation literacy and reading confidence.</strong> Meena M Balgopal (Colorado State University)*; Christine Folks (Colorado State University); Giovana Matos Franco (Colorado State University); Paul Ode (Colorado State University)</td>
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<td><strong>Comparing Self-reported Impacts of Scientist Spotlights in Lower- and Upper-Division Courses.</strong> Shaelin Chong (UC San Diego)<em>; Jerick Kim (UC San Diego)</em>; Melinda T Owens (UC San Diego)</td>
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<td>11:30 AM – 12:00 PM</td>
<td>Lunch</td>
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<td>Poster Session</td>
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<td>Closing and Scavenger Hunt Giveaway</td>
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How to integrate science communication into your biology course using active learning.
Mark A. Sarvary (Cornell University)*; Kitty Gifford (Cornell University)

Workshop Description: Are you interested in teaching your students how to effectively communicate science outside traditional conference seminars, posters, and journal articles? Join this workshop and learn how to teach students to engage non-technical audiences. Practice teaching science communication at your comfort level, from embedding small exercises into your biology course to creating a science communication strategy that tells your students' science story impactfully. In today's world, sharing scientific discoveries with the public is not just the responsibility of professional communicators but also a necessary skill for all scholars. This workshop is co-taught by a scientist and communication professional to provide hands-on experiences and real-world examples. Participants will learn how to help students fill their science communication “toolbox,” learning how to engage a variety of audiences, including the public, journalists, and policymakers. College undergraduates are no longer only consumers but also producers of scientific information. Employees and postgraduate programs are showing an increasing interest in undergraduates with advanced communication and interpersonal skills. The “Vision and Change in Undergraduate Biology” (AAAS, 2011) identified communication as one of the core competencies for biology students and science communication education should no longer be a postgraduate afterthought, but rather a foundation of undergraduate biology education. Science communication training can help students understand the scientific process, become science literate, identify the role of science in society, and shape their interdisciplinary views. Teaching science communication can happen in many different formats: one-day-long workshops, activities embedded into STEM courses, semester-long courses dedicated only to communication, or in institute-wide undergraduate minors or majors. Regardless of the format, instructors should use evidence-based teaching practices. With the advancement of education research, it is clear to all instructors that students learn better by doing, and science communication has many applied components that can be taught using these active learning techniques. In this workshop, the co-presenters want to share some of the active learning techniques they have been using in their applied science communication course at Cornell University and at Shoals Marine Laboratory. Ideas about how to teach information literacy, encourage storytelling, assess audiences, or use social media will be shared. They will also discuss curriculum development using Bloom's Taxonomy, and the benefits and challenges of building a university-wide science communication program. The focus of this workshop will be hands-on activities. The presenters will discuss and demonstrate many active learning exercises that the attendees will be able to try. Attendees will be engaged in all the teaching activities as participants: for example, they will use think-pair-share, games, role-playing, and more to experience these classroom activities. Attendees are encouraged to bring their own teaching techniques to share. Attendees will walk away with an inventory of active learning methods that they can implement in their own classes.
Developing No-Code, AI-Enhanced, Online Study Tools for Biology Students: A Beginner's Workshop. Keefe Reuther (UC San Diego)*; Liam O Mueller (UC San Diego); Grace Constantian (UC San Diego); Albert Nguyen (UC San Diego)

Workshop Description: In the era of generative artificial intelligence (GenAI) tools, like ChatGPT, educators face new challenges. They must integrate these transformative technologies into curricula to enhance student learning and prepare students with the skills they will need to leverage GenAI in industry after graduation (Agathokleous et al., 2023). Discipline-Based Education Research (DBER) on the use of this technology is crucial, as it provides evidence-based strategies for its appropriate use (Lodge et al., 2023; Yeralan & Ancona Lee, 2023). This hands-on workshop will guide participants through the development of an interactive, AI-driven web application that provides formative feedback to students as well as a framework for evaluating its effectiveness.

Targeted at individuals eager to learn about generative AI tools such as ChatGPT, this workshop requires no prior technical knowledge or experience in web design or computer programming. By the session's conclusion, participants will have created their own web application, which they can use to provide the most advanced ChatGPT model at no cost to all their students. This method takes advantage of OpenAI's API function, offering enhanced privacy and giving educators and researchers significantly more control over the creation and evaluation of learning activities. In line with the principles of open educational resources (OER) and open-source code, a proof-of-concept web application developed by the workshop facilitators will be presented as a foundational example (https://schemastudy.streamlit.app/).

Anchored in schema theory, this online active learning activity encourages students to engage deeply with definitions, connections, and applications of course concepts (Duschl, 2019). Participants are presented with a randomly selected term from a list compiled by the instructor and are prompted to construct a schema around it. Using student responses and instructor-prepared prompts, a real-time conversation with a ChatGPT tutor trained to offer precise formative feedback and engage in Socratic questioning is initiated (Wang et al., 2023; Lloyd et al., 2022).

Workshop attendees will employ ChatGPT to curate their term lists and schemas, as well as to personalize and test their instructions for both students and the chatbot. With the aid of thorough documentation, participants will create GitHub and Streamlit accounts, clone a public repository, adapt it with their curated content, and launch a live web application. After setting up their version of the app template, participants will simulate student interactions, allowing them to use a design-based research approach to iteratively refine feedback accuracy and quality (Scott et al., 2020). The workshop will conclude with a structured discussion on the ethical integration of AI tools into biology education, focusing on potential impacts, challenges, and future directions for DBER (Baidoo-Anu & Ansah, 2023; Farrelly & Baker, 2023). At the end of the session, attendees will have a customizable web application to share with their students and a strategy for ethically leveraging the power of generative AI in biology education.
Crossing Boundaries: Uniting Math and Biology Through Modeling. Kristine Squillace Stenlund (UMN)*; Anita Schuchardt (University of Minnesota)

Workshop Description: Calls to action have emphasized the need to help students understand connections between mathematics and biology (AAAS, 2011; Jungck, 2020). However, in science classrooms, mathematics is most commonly used as a tool for computation, data analysis, or data representation in service of science (Eichenlaub & Reddish, 2019). Therefore, students struggle to make connections between mathematical representations and scientific phenomena which limits them to solutions they’ve memorized or previously encountered problems, rather than being able to apply their knowledge to new situations (Bing & Reddish, 2009; Taasoobshirazi & Glynn, 2009). Model-based instruction may foster formation of connections between mathematics and science (Desi, 2023; Hestenes, 2010) and increased conceptual understanding and quantitative problem solving (Schuchardt & Schunn, 2016).

This workshop will provide an opportunity to engage with a mathematical modeling curriculum as students, discuss features of the curriculum that promote modeling and in-depth discussion of scientific ideas and generate ideas about how the mathematical modeling could be adapted to their classrooms.

Workshop Outcomes
By the end of the workshop, participants will be able to:
1. Identify affordances and constraints to mathematical modeling
2. Identify pedagogical moves and curriculum design features that can promote student discussion of scientific ideas during mathematical modeling
3. Apply and adapt mathematical modeling to their own classroom content

Participants will leave with an experience with mathematical modeling, adding awareness of another effective teaching strategy to their toolkit and providing a basis for modification of their current teaching strategies.

Workshop Stipend
To support workshop and conference attendance, an $800 stipend will be awarded for up to 20 participants from community colleges, tribal colleges or non-R1 universities to defray the cost of attending the workshop and SABER registration.
Structural Equation Modeling: Using JASP as a Companion to R. Ashli M Wright (Florida International University)*; Alexander Eden (Florida International University)

Workshop Description: Structural equation modeling (SEM) can be used to develop instruments in biology education research, but can be challenging to use. JASP is a statistical application that can assist early career researchers in developing and validating instruments with SEM. This interactive workshop will provide participants with the skills necessary to incorporate SEM into their own contexts. The workshop begins with an overview of SEM including factor analysis and applications. This will be followed by a demonstration of the JASP software, where participants can use their own data or data that the presenters will provide. The bulk of the time that remains will be dedicated to an open-ended collaborative time where participants can engage with each other while the presenters facilitate discussion. In the end, major takeaways will be discussed and shared as a group, with future directions identified. Ultimately, participants will leave this workshop with new confidence with SEM and ready to not only use it in their practice but to train mentees as well.
LONG TALK ABSTRACT

Investigations into undergraduate students’ experiences of scientific failure and the impact of identity on perceptions of failure.
Sandhya Krishnan (University of Colorado Boulder)*; Jason Corwin (University of Colorado Boulder); Joseph Harsh (James Madison University); Isabel Cobb (James Madison University); Lisa A Corwin (University of Colorado Boulder)*

Abstract:

Literature & Rationale
Scientists consider experiences of failure as part of the scientific process, as opportunities for further investigation, and as learning experiences (e.g., Simpson & Maltese, 2017). This is a stark contrast to students’ academic failure experiences, which they see as confirmation that they do not belong in science (e.g., Holmegaard et al., 2014). Failure can be a difficult experience to process and can have negative effects for students who are operating in high-stakes environments where they feel they cannot afford setbacks (e.g., Nelson et al., 2013; Cooper et al., 2020). These failure experiences can prompt students’ decision to leave scientific disciplines (Chen, 2013), especially for students with minoritized identities (Riegle-Crumb et al., 2019; Seymour & Hunter, 2019). This impacts students’ conceptions of their abilities and contributes to the lack of diverse perspectives in STEM.

However, there may be routes to help students both learn to better cope with failure and develop an understanding of failure as an opportunity for learning. Not all student learning contexts frame failure as detrimental; students who encounter scientific failures in undergraduate research experiences - independent or course-based (UREs or CUREs) - have described these failures as formative (Krishnan et al., 2021; Gin et al, 2018, Goodwin, 2021), contributing to their epistemological learning and ability to productively cope and overcome setbacks. How, then, do we best leverage research-based learning contexts?

Research aims & Philosophies
Our research addresses two aims: 1) We aim to describe how students personal failure orientations (i.e., malleable characteristics influencing their response to challenge) change over the course of CURE participation and as a result of experiencing research-based failures, and 2) We aim to describe students’ experiences and perceptions of failure as they relate to students’ own identities to better understand how students holding minoritized identities situate their own experiences and identities in this context. Together these aims can inform instruction in contexts where students are exposed to scientific failure.

To characterize the interaction of students’ identities with challenge and failure experiences, we leverage phenomenological variant ecological systems theory (PVEST, Spencer et al., 1997). PVEST is a framework that describes the interplay of systems - including direct support, such as family and friends; work and educational environments, such as courses and institutions; and the broader cultural and political climate – with student experiences to influence both immediate and long-term coping with stressors and ultimately identity formation. To characterize students’
experiences of science failure we utilize multiple integrated frameworks from psychology (Authors, 2019) to inform students’ experiences as a complex phenomenon involving multiple, interacting intrapersonal factors which students bring into the learning space, such as fear of failure (Cacciotti, 2015), goal orientation (Chen et al., 2009), and instructor trust Cavanaugh et al., 2018). Finally, this work uses mixed methods methodology, specifically parallel convergent mixed methods design (Cresswell & Clark, 2006), a framework that helps corroborate or explain findings across multiple types of data analyses.

Prior Research
Together the researchers that will be presenting this work have published or have in consideration 5 peer-reviewed manuscripts on this topic. These manuscripts include: a theoretical essay (Authors, 2019); two papers studying students’ meaning-making around failure in independent research settings (Authors, in peer review); and two papers studying student learning outcomes in CURE contexts intentionally structured for failure opportunities (Authors, 2018; 2022). Primary findings from these works captured: students rationalizing failure in describing what they had experienced, how they had experienced it, and providing justification for why it mattered (Authors, 2021); that explicit guidance on how to cope with failure and opportunities to iterate support positive student outcomes (Authors, 2021); and students reporting adaptive coping responses around failures in their lab work, even when experiencing negative emotions (Authors, 2022). These findings informed the development and implementation of the next series of projects on the topic of failure.

Research Design
To address Aim 1 and 2, we conducted a series of investigations in CUREs constituting a multi-year mixed methods study. We collected data at diverse institution types (16, including community colleges, MSIs, PUIs), disciplinary contexts (e.g., mainly biology and also chemistry and math), and types of CURE courses. Conducting multiple surveys and interviews in 20 different CUREs, we surveyed 1320 students. We discuss 3 investigations from this multi-year multi-institution study that address: (1) the influence of science failures on changes to students’ personal failure orientations and the role that demographic identities may have in that change, (2) how learning from failure may also influence changes to students’ personal failure orientations and the role of demographic identities in that change (2) how students’ identities may impact their perception and experience of failure.

Surveys conducted at three timepoints (pre-, mid-, post-CURE) collected demographic data, measured psychosocial constructs known to elicit students’ personal failure orientations, and asked open-ended questions about students’ salient identities and perceptions of failure. We only used data from students who fully completed all surveys (522) for the investigations described below.

Analyses & Interpretations
Investigations 1 & 2 (Quantitative). Empirical and theoretical work describe how orientations (e.g., fear of failure, goal orientation) influence students’ approach to challenges and response to failure, such that students certain orientations may avoid challenges and respond with
negative coping outcomes to failure and others may willingly or even enthusiastically engage with challenge and respond productively to failure. We used mixed model regression to quantitatively test for changes in specific intrapersonal constructs based on whether students experienced failure in their CURE settings. We tested the relationships between changes to students’ intrapersonal constructs (fear of failure, goal orientation, instructor trust - tested pre/post), whether they experienced research failures (investigation 1) and whether those students learned from failure (Investigation 2) and whether students held particular demographic identities (race/ethnicity or first generation). In general, we found that when students came into the CURE with more positive orientation towards failure, they were more likely to learn from the experience of failure. More specific results will be shared at SABER 2024.

Investigation 3 (Qualitative). An open-response item in the final survey asked students how they perceived the relationship between their salient identities and failure. Engaging in reflexive thematic analysis (Braun & Clarke, 2022), we coded student responses inductively, organized those codes deductively within PVEST processes, developed themes based on our code groupings, and revised and refined themes through iteration and collaborative reflection. An important theme that arose from using PVEST was the framing of identities as strengths to aid in navigating failures, as evidenced in this example of a student who wrote that “I think being queer and neurodivergent has made me very resilient, so I see failure as a roadblock rather than the end of the road.” Additional themes will be shared at SABER 2024.

Synthesis. We will present the merging of the results from the three investigations at SABER 2024.
SHORT TALK ABSTRACTS

Friday, July 12, 2024

Concurrent Short Talks - Session 1

Session 1_A

How to Write Your CourseSource Manuscript: Outcomes and Lessons Learned From Five Years of Writing Studio Workshops.

Sharleen Flowers (University of Colorado, Boulder)*; Zachary Hazlett (University of Colorado, Boulder); Marie Ramirez (Cornell University); Kira Treibergs (Cornell University); Erin Vinson (Codon Learning); Michelle Smith (Cornell University); Jenny Knight (University of Colorado, Boulder)

Abstract:
Study Context: CourseSource is a peer-reviewed, open-access journal that publishes Open Educational Resources (OERs) for undergraduate biology and physics courses and labs. Since OERs are free, they can increase access to educational materials for teachers and provide more equitable resources for students (Griffiths et al., 2018). Thus, there is a growing demand for more OERs that are evidence-based and inclusive. However, research on the OER life cycle has shown that instructors adapt and use resources much more frequently than they share their own materials (Beaven, 2018). To address this need, the editorial team at CourseSource designed a Writing Studio workshop based on the “developing reflective teachers” change strategy model (Donovan et al., 2015; Henderson et al., 2011). This model encourages building networks of instructors to collaboratively consider how they develop and teach materials. The Writing Studio has been offered multiple times over the past five years, with the intent of helping instructors share their resources by publishing in CourseSource. We investigated the efficacy of the Writing Studios to discover (RQ1) what characteristics predict whether participants submit their article for publication, (RQ2) whether the Writing Studio helped participants achieve their goals, and (RQ3) what strategies do current participants suggest to help future instructors publish their articles.

Study/Research Design: From 2018–2023, we delivered 11 Writing Studios to 188 participants. Participants learned about the different features and requirements of a CourseSource Lesson article and engaged in writing and peer review. Writing Studios differed in modality and length: in-person short (three days), online short (three days), and online long (several weeks). We administered two surveys with free-response questions about workshop goals to four Writing Studio cohorts before and after the workshop. Additionally, we distributed a follow-up survey in Fall 2023 to all participants, with free-response reflection questions on their experience. To answer RQ1, we performed binomial linear regression modeling in R using participant demographic data. For RQ2 and RQ3, we analyzed open-ended responses from the surveys using thematic coding.

Analyses and Interpretations: (RQ1) Overall, 38.8% of participants submitted their article. Publication rates were highest for graduate students and postdocs (52% and 45%, respectively) and for participants who came from either Doctorate-granting or Primarily Undergraduate Institutions (PUIs) (42% and 45%, respectively). (RQ2) For participants who
submitted/published their article, most felt the Writing Studio helped them accomplish their goals (85%) and described feeling supported by the Writing Studio’s structure and materials. On the other hand, participants who did not submit their article mostly felt they did not accomplish their goals (79%), describing barriers such as time management and job responsibilities. (RQ3) To make the Writing Studio more useful, participants most commonly suggested increasing the workshop’s length and expanding opportunities for peer feedback. Participants who had published their article suggested providing follow-up reminders or meetings after the Writing Studio’s conclusion to help navigate the submission process. Additionally, participants who did not publish recommended giving more information prior to the studio to help gauge readiness.

Contribution: Previous studies showed that between 19-28% of instructors in higher education share OERs (Admiraal, 2022; Senn et al., 2022). The Writing Studios yielded a more successful outcome for sharing (38.8%), but more work is needed to increase publication rates and better support participants. Although trainees (graduate students and postdocs) were outnumbered by faculty participants, the higher publication rates from trainees suggests an additional opportunity. By explicitly encouraging their participation in future Writing Studios, early-career academics can bring new educational ideas to the OER community while bolstering their CVs and gaining valuable writing experience. There is also a need to more effectively engage participants who may have less time or resources. By implementing the participants’ suggestions and offering more post-workshop support, we aim to create a more supportive Writing Studio and help more authors engage in sharing their resources. Lastly, we encourage other communities to leverage these recommendations and suggested improvements to help increase the number of published high-quality OERs.

Understanding biology undergraduates’ mentoring experiences at a Hispanic-Serving Institution and their effect on student career development.

Hector G Loyola Irizarry (Florida International University)*; Krista Donis (Florida International University); Roxana Gonzalez (University at Buffalo); Mia Uzcategui (Florida International University); Rocio Benabentos (Florida International University); Jessica Liberles (Florida International University); Melissa McCartney (University at Buffalo)

Abstract:
Study Context: Mentorship is critical for the success of undergraduates in science, technology, engineering, and mathematics (STEM) disciplines (Byars-Winston & Dahlberg, 2019). Since STEM professionals who identify as belonging to historically marginalized groups face various challenges throughout their career (Estrada et al., 2016; Flores et al., 2023; Yadav et al., 2020), it is crucial to understand and bolster the mentoring experiences they obtain as undergraduates. Current literature surrounding biology students’ mentoring experiences focuses largely on the evaluation of structured mentoring or research programs (Aikens et al., 2017; Behar-Horenstein et al., 2010; Johnson et al., 2015; Palmer et al., 2015). There is a lack of knowledge surrounding a typical biology undergraduate student’s mentoring experiences, such as the factors that influence which biology undergraduates identify a mentor, especially when this is done without the support of a structured mentoring program, and the career support mentors provide once they are secured.

Study/Research Design: We analyzed responses from a large dataset obtained from biology undergraduates at a research-intensive (R1) Hispanic-Serving Institution (HSI) in Spring 2023 (n=1427). To account for the multitude of factors that can influence student career development, the study is grounded in both Social-Cognitive Career Theory (Lent et al., 1994)
and Possible Selves frameworks (ECCLES, 2009; Markus & Nurius, 1986). We also utilized Nora and Crisp’s model of mentoring (Nora & Crisp, 2007) to validate a questionnaire focusing on two domains of mentorship support, Degree and Career Support (DCS) and Existence of a Role Model (ERM).

Analyses and Interpretations: Only 324 (23%) students indicated the presence of a mentor at their institution. Various factors were correlated with whether or not a student reports a mentor at their institution, such as ethnic or racial background ($\chi^2=13.91, \text{df}=6, p=0.0311$), number of credit hours for the semester ($\chi^2=7.96, \text{df}=3, p=0.046$), and whether a student reports having participated in an undergraduate research experience (Fisher’s exact, $p=1.45 \times 10^{-5}$). Additionally, we observed that students who reported having a mentor at the institution also report higher science identities (Mann-Whitney, $p=0.004$), sense of belonging to the biology department (Mann-Whitney, $p=9.89 \times 10^{-5}$), GPA (Mann-Whitney, $p=0.025$), and number of career strategies (Mann-Whitney, $p=4.90 \times 10^{-4}$), emphasizing the potential benefits students obtain from participating in mentoring experiences. Finally, we observed a relationship between student’s gender (Mann-Whitney, $p=0.026$) and ethnic or racial background (Kruskal-Wallis, $p=0.01$) and the support they obtain in the DCS domain, meaning that students who identify as gender or racial/ethnic minority groups report their mentors provide less support in this domain.

Contribution: Here, we present an overview of how a typical biology student’s mentoring experiences at a HSI can influence their career development. Through this work, we add to the current body of literature an analysis of factors that can influence whether students identify a mentor and the career support they obtain from their mentors. Together, our analyses show that although there are clear benefits for students to include mentoring experiences in biology undergraduate curricula, many students do not obtain the mentorship they need, and those that do might face racial- or gender-specific challenges that affect the level of career support they obtain from their mentors.

Moving more students from STEM degree to STEM workforce: is targeted career development the key?

Melissa McCartney (University at Buffalo)*; Roxana Gonzalez (University at Buffalo); Mia Uzcategui (Florida International University); Rocio Benabentos (Florida International University); Jessica Liberles (Florida International University)

Abstract:
for qualified graduates. Researchers have previously investigated variables such as demographics and attrition rates for the lack of STEM graduates available to fill job vacancies, however, there is potential for additional research examining the impact of career-related variables such as undergraduate career development courses (CDCs). Very little research has been conducted regarding structured career planning within undergraduate STEM initiatives, i.e. STEM-focused CDCs (Belser et al., 2018). The few studies available link CDCs to retention within STEM majors, however, retention in the major does not correlate with STEM graduates entering the STEM workforce (Villarejo et al., 2017; Rosenzweig et al., 2021). We should not assume that students are progressing toward their intended STEM careers simply because they have persisted in STEM. We may lose qualified STEM graduates simply because they do not know how to navigate the workforce.

Study/Research Design: Career development is even more challenging for marginalized students in STEM. Rottinghaus et al., (2018) cite an extreme underrepresentation of
marginalized students in a literature review of CDCs and discuss the importance for future research to consider various cultural factors, including race and ethnicity. To learn more about career development among marginalized populations, and to increase the career readiness of biology undergraduates at a Hispanic Serving Institution (HSI), we developed and implemented Careers+, a week-long workshop composed of career development modules grounded in Social Cognitive Career Theory (SCCT) and designed specifically for biology undergraduates. Modules were developed to target the three main factors of SCCT: 1) career goals and strategies, 2) career self-efficacy, and 3) career outcome expectations. Specifically, we tested whether a short CDC intervention could positively shift biology undergraduates’ career readiness (n=67).

Analyses and Interpretations: Pre- and post-questionnaires show positive shifts in all three SCCT factors (paired t-tests). We did not see a change in students’ career goals, however, sentiment analysis revealed that student goals became more positively written. In parallel, we saw an increase in the average number of strategies students use to reach these goals (4.04 strategies pre-Careers+; 5.13 strategies post-Careers+; p=0.002). Using a one-factor career self-efficacy assessment validated for our student population, we saw a significant and positive increase in student scores (4.33 pre-Careers+; 5.27 post-Careers+; p=0.00003; using a 6-point Likert scale). Using a three-factor career outcome expectations assessment validated for our student population, we saw significant and positive increases in student scores for the factor of gathering career information (4.89 pre-Careers+; 5.47 post-Careers+; p=0.003; using a 6-point Likert scale). In addition, we see positive shifts in student networking behaviors, career deliverables (e.g. I have updated my resume), and career behaviors (e.g. I can actively map my future). Finally, we collected feedback on individual modules to determine how and/or why each module impacts student career readiness and how each module connects to the three main factors of SCCT. Longitudinal analysis on whether any of these positive shifts were retained post-Careers+ is ongoing.

Contribution: Our data show that CDCs can be targeted specifically to biology undergraduates with a simple implementation and encouraging results. As Careers+ was implemented at an HSI, our data set is one of the first to focus on career development for historically marginalized populations and provides much needed data on interventions with the potential to minimize the loss of marginalized populations during the transition from undergraduate institutions into the STEM workforce. CDCs such as Careers+ should be considered as a lever for increasing diversity in the STEM workforce.

Investigating Career and Research Experience Access Through Evidence (iCREATE) at a Hispanic-Serving Institution.

Roxana Gonzalez (University at Buffalo)*; Hector G Loyola Irizarry (Florida International University); Mia Uzcategui (Florida International University); Wensong Wu (Florida International University); Rocio Benabentos (Florida International University); Jessica Liberles (Florida International University); Melissa McCartney (University at Buffalo)
Session 1_B


Mariel Pfeifer (University of Mississippi)*; Ariel J Chasen (UT Austin)

Abstract:
Study Context:
There is now an interest within discipline-based education research to use critical frameworks in the design, execution, and dissemination of research (Metcalf, 2016; Patrick et al., 2022). Yet many discipline-based education researchers (DBERs) have had limited opportunities to receive training related to critical frameworks. Limited training opportunities can make it challenging for DBERs to understand the origins, tenets, and appropriate applications of a critical framework in their scholarship (e.g., Greene, 2022). Given this gap in knowledge, we offer a theoretical paper about one form of critical theory called Disability Critical Race Studies (DisCrit) (Annamma et al., 2013). DisCrit seeks to unveil the ways in which interlocking systems of oppression—i.e., ableism and racism—manifest within educational systems. The theory is made of seven tenets that can be applied to form research questions and that informs the choices researchers make as they go about research (Annamma et al., 2013). This work builds off of previous biology education research (BER) literature that has explored disability and access in pedagogical settings (Reinholz & Ridgway, 2021; Gin et al., 2020) by bringing these concepts into methodological considerations.

Study/Research Design:
We aimed to facilitate a broader awareness of DisCrit and how researchers can use the tenets of the theory to guide their work. We present a theoretical case study to demonstrate how different approaches to research can best embody the DisCrit framework that centers the lived experiences of disabled and racially marginalized individuals. In designing this theoretical case study, we sought feedback from both BER and DisCrit scholars who have widely published in both fields. We walk the audience through the research process from conceptualizing a study to disseminating findings and identify key moments and strategies that can be employed when using a critical framework such as DisCrit. We leverage existing scholarship and our lived disabled experience to discuss how biology education researchers can design, execute, and communicate research findings. We discuss the tenets of DisCrit and offer example research questions that illustrate how the framework could be applied in biology education research. We also propose that researchers engaging in DisCrit-informed and related studies generate “Access and Equity” maps and provide an example of one via our case study, to make public the decisions researchers make as part of their commitment to center the voices of multiply marginalized people in their scholarship.

Analyses and Interpretations:
In generating the practices and suggestions in our theoretical case study, we consulted DisCrit and BER scholars and discussed to consensus themes and strategies to include. DisCrit encourages researchers to engage in transformative intersectional analyses of their data to bring about the changes our educational systems need to support access, equity, inclusion, and justice for disabled people of color. We offer suggestions for researchers new to intersectional analyses some strategies they can use and adapt for their own study’s contexts by leveraging work from Grzanka (2020). We engage in this discussion by demonstrating clear examples of what intersectionality is, and what intersectionality is not. We illuminate how BER scholars can reflect on and improve this analysis in their own work.
Our analysis also extends to entrenched dissemination practices in our field. The theoretical case study offers ideas for engaging in intellectual activism beyond academic publishing practices. We discuss how a DisCrit framework, for example, might call for examining which populations are actually benefiting from how we share our findings. The case we present will prompt attendees to interrogate their aims and approaches to research at multiple stages through the process.

Contribution:
Our theoretical paper adds to the biology education literature by introducing DisCrit to the field and offering strategies for researchers to use in their ongoing and future work. In particular, we propose that BER scholars consider using our novel approach of ‘Access and Equity maps’ as part of their commitment to centering the voices of people multiply marginalized in traditional research using DisCrit as an exemplar for this approach. The BER community has shown prior interest in topics related to disability and critical theories (Reinholz & Ridgway, 2021; Gin et al., 2020), thus we anticipate our paper will be of general interest and importance. Our theoretical paper provides a roadmap for BER scholars interested in using critical theories, such as DisCrit, in their work as well as advancing conversation on the use of critical theories in our field.

Can an interdisciplinary and inter-institutional Community of Transformation promote collaboration and STEM education reform? Yes!

Ethan X Roberts (California State University, Sacramento)*; Catherine Ishikawa (California State University, Sacramento); Kelly McDonald (California State University, Sacramento)

Abstract:

STUDY CONTEXT
Communities of Transformation (CoT’s) are professional groups interested in changing the ways its members engage in a particular practice (e.g. teaching) by creating intellectual spaces that leverage community knowledge and expertise. In academia, change researchers have suggested that relationships formed between faculty are important for creating and maintaining change; therefore, incorporating community and relationship-building activities into professional development is recommended (Kezar et al 2018). The Science of Team Science literature provides promising examples of how activities designed around networking, disciplinary humility, and shared goals can promote interdisciplinary collaboration in healthcare professionals, (e.g. Stokols et al 2012) though to our knowledge this framework has not been applied in a STEM education context.

The SIRIUS II project is a five-year long NSF-supported CoT aimed at supporting faculty in designing and implementing curricula called course-based Authentic Learning Experiences (our desired change outcome). An underlying assumption of SIRIUS II change theory is that collaboration will translate to faculty curricula development and implementation. In this project, we used the Science of Team Science (SoTS) literature as a framework to foster collaboration between SIRIUS II faculty, who come from diverse disciplines and institution types. We present evidence that this model promotes collaboration between faculty and discuss the extent to which collaborations supported curricula development.

RESEARCH DESIGN
In year one of the SIRIUS II project, we invited faculty from 5 academic institutions (4 community colleges and 1 four-year university) and 8 STEM disciplines to participate in a Summer Institute to promote community-building and create a shared vision of curriculum development.
reform (n=35 faculty). SoTS-inspired activities consisted of two open-ended reflections prompting faculty to identify norms unique to their disciplines and teaching institutions (IRB-19-20-289). Faculty first answered these questions individually, and then later discussed their responses in mixed-discipline breakout rooms. In year three of the project, faculty were given social network surveys to identify collaborative relationships. All respondents (n=25) participated in follow-up semi-structured interviews to clarify the nature of their collaborations. Interviews were held, recorded, and transcribed using Zoom. Codebook development and analysis was done through the lens of the Theory of Planned Behavior (Ajzen 1991), which asserts that people’s intentions to perform specific behaviors are explained by: 1) individual attitudes toward change, 2) subjective norms [e.g. “what does this community expect of me?”], and 3) perceived behavioral control. Interview transcripts were analyzed using a constant comparisons coding method (Glaser and Strauss 1967; see also Kolb 2012) with the Theory of Planned Behavior criteria serving as a priori code categories.

ANALYSIS AND INTERPRETATIONS
Twenty-two of the twenty-five survey respondents participated in at least one collaboration prior to year three of the SIRIUS II project. When interviewed, all faculty expressed positive attitudes toward collaboration, usually by describing potential benefits for themselves, their students, or their curricula. When analyzing transcripts for subjective norms, we found that faculty did not report feeling expectations from SIRIUS II colleagues/leadership. Instead, they expressed a variety of internally motivated expectations for their future community engagement and project development (e.g. “...I felt that I needed to make it a bigger project”). These findings suggest early community-building activities designed around SoTS influenced faculty attitudes and subjective norms as described by the Theory of Planned Behavior.

Lastly, faculty shared a wide range of challenges preventing them from developing their curricula, including logistical challenges (e.g. time constraints, conflicting responsibilities) and social challenges (e.g. difficulty initiating new connections or maintaining existing ones). Faculty also identified assets that directly motivated and enabled curricula development; for example, they commonly said that SIRIUS II leadership were helpful and made them feel included, and that they learned from the successes and failures of their colleagues. This provides early evidence that collaborations between faculty enable change in alignment with the SIRIUS II change theory.

CONTRIBUTION
To our knowledge, this study is the first to apply the SoTS framework to a STEM education professional development context. This study also supports the idea that collaborations between academic professionals directly support faculty change in a CoT. While these findings are specific to the SIRIUS II project, we feel that communicating this work could benefit change leaders and researchers operating in similar contexts.

Development and Validation of the Team Member Perceptions of Instructional Change Collaborations (TM-PICC) Survey.

Amreen Thompson, Alice Olmstead, Madison Fitzgerald-Russell, Diana Sachmpazidi, Cynthia Luxford, Andrea Beach, Charles Henderson.

Abstract:
Efforts to improve US STEM education have begun to emphasize systemic change efforts over individual efforts, highlighting the importance of instructional change teams in revising or creating courses. However, not all teams are successful, and poorly conceived or dysfunctional
teams waste resources. In this talk, we describe developing and validating a survey instrument, the Team Member Perceptions of Instructional Change Collaborations (TM-PICC). It describes team members' perceptions of their experiences on an instructional change team.

This survey fills an important niche in the higher education change system. Existing surveys on team effectiveness in higher education are limited, mostly focusing on undergraduate student teamwork (e.g., Bravo et al. (2019); Britton et al. (2017); Ruiz Ulloa & Adams (2004); Varela & Mead (2018)). Surveys from other sectors often lack proper reporting of psychometric properties (Varela & Mead, 2018). In addition, while some measure relevant constructs such as communication (Anderson & West, 1998; Brannick et al., 1993), shared vision (Kahn & McDonough III, 1997; Millward & Jeffries, 2001), cohesion (Alexander et al., 2005; Anderson & West, 1998), they aren't tailored to higher education and may miss important aspects of the higher education landscape.

Previously (Author et al., 2019; Author1), we developed a model of instructional change teams. This model serves as the conceptual framework for the survey. Our model includes 5 Team Inputs, each with two subcategories: Nature of the Task (team origin story; prescribed task), Who Participates (team composition; team boundaries), Process Constraints (prescribed process; formalized roles), External Engagement (opportunities to gain/share information), and Access to Resources (administrator support; rewards) (Author et al., 2019). These 5 Team Inputs influence 5 team Processes and 3 Emergent States (Author et al., 2021). We identified The Team Processes: Strategic Leadership, Egalitarian Power Dynamics, Team Member Commitments, Effective Communication, and Clear Decision-Making Processes. The Emergent States are: Shared Vision, Psychological Safety, and Team Cohesion. These Team Processes and Emergent States cyclically influence each other and 4 Team Outcomes: Quality of Instructional Changes, Sustainability of Instructional Changes, Collaboration Changes, and Individual Changes (Author et al., 2019).

We've translated this model into a survey for researchers and practitioners to support instructional change teams. In our presentation, we'll outline the steps taken to guide the development and validation of our TM-PICC survey, following methods by Kane (1992, 2013) and Douglas et al. (2020). Qualitative stages of survey development included Cognitive Interviews (9 instructional change team members from 4 institutions), (2) Initial Item Development (3) Expert Review: Items presented to our NSF advisory board for review, (3) Think-Aloud Interviews: 3 instructional change team members, who provided feedback on items. To recruit participants, we located STEM instructional change projects by searching databases, primarily NSF, using relevant keywords and recent start dates. We distributed the survey via Qualtrics to 219 team members across 34 teams in 9 institutions, including 7 public doctoral universities and one private master's university. The final survey had 67 items and took about 14 minutes on average. Our response rate was 68%.

Next, we conducted a quantitative analysis of data collected for psychometric validation. To assess construct validity, we conducted Confirmatory Factor Analysis (CFA), Structural Equation Modeling (SEM), and Goodness of Fit statistics. To assess internal reliability, we focused on Cronbach’s $a$ and McDonald’s $\omega$ for each construct. We used descriptive statistics (e.g., mean, skewness, kurtosis) to understand better the range of data collected and the distribution of that data. SEM analysis revealed a poor fit. With a conservative threshold of 0.6, 5 Team Processes items and 4 Emergent States items were identified for potential removal due to low factor loadings. While most constructs showed strong initial alpha ($\alpha$) and omega ($\omega$) coefficients exceeding 0.7, Egalitarian Power Dynamics had marginal reliability and was removed from the survey.
Efforts to enhance survey usability involved removing redundant items, resulting in a streamlined 24-item survey. Re-evaluation of SEM models confirmed adequate factor loadings and internal consistency. The TM-PICC survey can serve as a tool for understanding instructional change team dynamics, benefiting project leaders, team members, and evaluators. TM-PICC results can help teams to initiate discussions about team functioning and fulfill evaluation needs. The TM-PICC survey can provide a starting point for future work to explore its applications in settings that involve teams, including diversity and equity initiatives.

Undergraduate Life Science Professors’ Perception of the Vision and Change Core Content and Competencies for Preparing Students for Science Careers.

Ashli M Wright (Florida International University)*; Melissa McCartney (University at Buffalo)

Abstract:
Study Context. The American Association for the Advancement of Science (AAAS) released the Vision and Change (VC) Framework to establish a consensus on the content and competencies necessary for undergraduate biology students to master upon completing their undergraduate studies to afford students the skills necessary to be successful in STEM careers (AAAS, 2009). There is an understanding of how professors define VC competencies, their expectations of mastery in those competencies (Clemmons, 2020), and how they incorporate the VC Core Content into their instruction (Chatzikyriakidou, 2022). However, our knowledge of professors’ perception of the importance of VC Core Content and Core Competencies, especially concerning student STEM career development, is lacking. Professors’ perspectives matter because they determine if and how instructional strategies are used in the classroom, and professors have autonomy in how certain content and skills are taught. Much of the literature focuses on curriculum development and pedagogical strategies, not professor perceptions of the content and skills. Student-focused data limits our understanding of teaching and learning.

The VC framework offers an opportunity to organize instructional practice around a consensus of the content and competencies necessary for the STEM workforce (McLaughlin, 2016). How professors allocate limited time and resources in prioritizing content and skills is important for improving student learning outcomes. As professional scientists themselves, professors are uniquely positioned to prepare the next generation of biologists, as they are keenly aware of the content and skills necessary to engage in the practice of science (Mohan, 2020). Professors may feel compelled to model what they perceive as necessary for students to excel, and since different professors possess specific content knowledge and skills, this may impact the content and skills students learn.

This study aims to determine professors’ familiarity with the VC Framework, determine professors’ perception of the importance of the VC Core Concepts and Core Competencies for STEM majors and careers, examine if there is an association between professors’ perception of VC Core Content and Core Competencies that are most important for STEM careers, and examine if there are differences between professors’ academic and professional experiences and their perception of VC Core Content and Core Competencies for STEM careers.

The impetus for conducting this study lies in the fact that preparing a future science workforce requires that students engage in the practices of science. Professors’ perceptions of epistemic practices can influence if and how scientific practices are taught and what scientific content and skills are prioritized with limited instructional time.
Study Design. A questionnaire containing the six-point Likert scale items was distributed via the listservs of professional organizations. Participants were asked demographic information about their academic, professional, and pedagogical background and experience. This exploratory study aimed to determine if there was an underlying pattern that emerged from professors' ranking of VC Core Content and Competencies.

Analyses and Interpretations. Descriptive and Inferential statistical analyses (Spearman’s Rho and t-tests)\(n = 83\) found that most professors were familiar with VC, ranked ‘evolution’ as the most critical content and ‘systems’ as the least important, and the ‘ability to apply the process of science’ as the most critical competency and ‘Integrate Science and Society’ as the least important competency. Professors’ ranking of VC Core Content and Core Competencies varied based on their field of study and their years of experience. Surprisingly, the competency of ‘ability to use modeling and simulation’ was ranked very low.

Contribution. Professors’ limited familiarity with the VC Framework reflects somewhat effective professional development and outreach efforts of state and local curriculum developers. Much more concerning is professors’ perception that the ‘ability to use modeling and simulation’ is the least important skill for STEM careers and majors. There are implications for teaching and learning the nature of science and beyond the classroom that include delineating the ontological and epistemic practices of the life sciences. These results can be used to develop faculty professional development focusing on the content and competencies that may be overlooked or undervalued in instructional practice when preparing students for science careers. Further research is needed with an increased sample size and qualitative data collection and analysis to understand this phenomenon further. This study lays the groundwork for developing a theory of instructional decision-making to improve epistemic practices that students need to succeed in science careers.

Session 1_C

Characterizing Students’ Epistemic Networks for Reasoning about Natural Selection.

Julia Gouvea (Tufts University)*; Sugat Dabholkar (Tufts University); Scott Benjamin (Bunker Hill Community College); Sukanya Chakraborty (Florida State University)

Abstract:

Introduction
Natural selection is a complex concept; Expert-like understandings of natural selection integrate multiple ideas that span different levels of biological organization from genetics, to organismal traits, to populations (e.g. Dauer et al., 2013). Research on students’ developing conceptual ecologies of natural selection describe students as holding multiple conceptions, some of which may be contradictory (Nehm & Reilly, 2007). To support students in integrating their conceptions and activating them in appropriate ways, research is needed to explore patterns of when and why novice students activate different ideas in different contexts.

A growing body of work suggests that features of assessment questions such as the taxon, trait, and direction of evolution (i.e. loss or gain) influence the conceptions that students activate (e.g. Nehm & Ha, 2011; Heredia et al., 2016; Grunspan et al., 2021). In this study we extend this work to consider how students’ interpretations of what they are being asked influences activation patterns. Southerland et al., (2001) found that middle school students activated different conceptual elements depending on how they interpreted the question posed...
to them. When students interpreted the question as asking them to explain how the trait might have evolved versus asking why the trait evolved they shared different ideas. We conducted an analysis of interviews with eight community college students who were interviewed about how various traits evolved. We ask, how do the patterns of knowledge elements activation shift with different interpretations of the question (what we will refer to as interpretative context).

Study Design
Our analyses involved two rounds of qualitative coding followed by epistemic network analysis. One round of coding focused on characterizing students’ interpretations of what was being asked of them. For example, if a student was asked how a trait evolved, but answered by describing the environmental conditions that would have made the evolution of that trait favorable, we coded this portion of the interview as about “why” a trait evolved. Three interpretative contexts that emerged across all interviews were: how did the trait evolve (How), why did the trait evolve (Why), and what is the origin of the trait (Origin). A second round of coding identified the presence or absence of different knowledge elements related to natural selection including: variation, inheritance, differential success, use/disuse, need/lack of need, genetic basis, adaptive function, physiological mechanisms, and environment.

We then used epistemic network analysis (ENA) to create network models that capture how patterns of knowledge element activation relate to interpretive context. ENA provides an effective way to create visual representations of weighted connections (links) between networked elements (nodes) and quantitatively compare the networks (Shaffer et al., 2016). Such representations and comparisons have been effective to study student learning as they participated in different kinds of knowledge building activities (e.g., Arastoopour Irgens et al., 2020; Oshima et al., 2020).

Analyses and Interpretation
The ENA model showed statistically significant differences between clusters of knowledge elements for three contexts: Why, How and Origin. For example, a Mann-Whitney test showed that along both X and Y axes, Why (X-Mdn=-0.63, Y-Mdn=0.03, N=4, ) was statistically significantly different (U=0, p=0.03) from How (X-Mdn=X-0.42, Y-Mdn= Mdn=0.33, N=4).

We discuss what these differences mean in terms of students’ use of knowledge elements in their reasoning within a specific interpretive context. For example, connections between the nodes, need/lack of need, environment, and adaptive function were prominent in the Why context, suggesting that students invoke ideas about “need” when they are attempting to describe the conditions that led to a trait’s evolution. In a How context, we found connections among physiological mechanisms, inheritance, and differential success, suggesting that students activate ideas both about how traits change physiologically and how trait frequencies change at the population level.

Contribution
In order to understand patterns in student reasoning about an idea as complex as natural selection, it is important to understand how and why students are activating different ideas from their conceptual ecologies. This work begins to identify contextual patterns that predict the activation of specific ideas which may be used by researchers and educators to support conceptual development. In addition, we discuss how understanding the context in which inconsistent or contradictory ideas arise can inform efforts to support educators in identifying and helping students reconcile these inconsistencies through explicit attention to interpretative context.
Are they cousins? Exploring student acceptance of common ancestry in evolution.

Taya Misheva (Syracuse University)*; Jason Wiles (Syracuse University)

Abstract:
Study Context: Evolution is a core concept of biology, yet many undergraduate biology students do not accept major aspects of evolution (Ferguson & Jensen, 2021). Efforts to identify the causes of evolution rejection and to develop teaching strategies leading to increased acceptance both rely on surveys that measure evolution acceptance. Over the past 25 years, efforts to accurately measure student acceptance of evolution have led to the development of several survey tools. One persistent challenge has been constructing a survey that accurately characterizes not only students who either fully accept or fully reject evolution, but also those who exhibit partial acceptance. Most existing surveys can identify whether a student exhibits partial acceptance, but do not attempt to elucidate the content of those mixed views (Barnes et al., 2024). One survey (the I-SEA) sought to address this shortcoming by disentangling “evolution acceptance” into acceptance of micro-, macro-, and human evolution, as measured on separate subscales (Nadelson & Southerland, 2012). Yet resent research suggests that these subscales may still obscure further internal divisions (Sbeglia & Nehm, 2019; unpublished data). The goal of our current study is to improve the ability of future surveys to accurately characterize partial acceptance of evolution. Aligned with recommended standard practice for survey development (AMEE Guide #87), we are conducting a qualitative interview study exploring undergraduate student reasoning on acceptance vs. rejection of evolutionary concepts.

Study Design: Research questions: (1) On the tree of life, where do students usually draw the line between accepting and rejecting shared ancestry of non-human species, and what reasoning do they use? (2) Are students more likely to accept shared ancestry among some clades than among others (e.g., plants vs. animals)? (3) What reasoning do students use when deciding whether to accept the relatedness of modern humans to various primate and non-primate species? We explored these questions via semi-structured interviews with undergraduate students from different religious backgrounds. We recruited students who do not fully accept evolution by reaching out to introductory psychology students with low scores on the I-SEA and to various religious student organizations. During interviews, participants are shown multiple pairs of species ranging from very closely related to very distantly related, and asked if they think the pair may share a common ancestor, and why or why not. At the end of an interview, participants are asked to describe their personal views on evolution and the origins of life. Participants take the I-SEA survey before the interview, and a demographic survey after the interview.

Analyses and Interpretations: We are using the constant comparative method (Saldaña, 2021) to qualitatively analyze the data and have identified several trends among the interviews thus far. For the first question, we found that most participants accept the shared ancestry of species within the same family or genus, but are more likely to reject shared ancestry for species that are related at the level of class or higher. Participants typically cite anatomical similarities (or differences) and a terrestrial vs. aquatic habitat as their reasoning. For the second question, we found that participants are able to supply clear reasoning when comparing animals, but often lack strong views and struggle to provide reasoning when comparing plants, fungi, or single-celled organisms. Some have cited lower familiarity with non-animal species as a main reason for this discrepancy. For the third question, we found that (a) most participants see earlier hominins (e.g. Neanderthals) as essentially human and (b) are often willing to accept or entertain the idea that God created humans via evolution from earlier
apes, yet (c) often reject shared ancestry between apes and other non-primate taxa, citing perceived lack of anatomical similarity.

Contribution: Despite supporting the overall notion of scale- and context-relevance in evolution acceptance, these findings refute the idea that the relevant distinctions lie between micro- vs. macroevolution, and human vs. non-human contexts (Nadelson & Southerland, 2012). This study instead suggests that, for students who partially accept evolution, the extent of anatomical and habitat similarity among high-level taxa are more salient considerations than speciation when deciding whether to accept shared ancestry. Furthermore, acceptance of human descent from apes can be part of an “orchard of life” stance, in which certain taxa arise via separate creation. Researchers and instructors who use peer-reviewed survey tools to measure student acceptance of evolution can use these findings to inform their interpretation of survey results or to inform ongoing efforts to further improve evolution acceptance survey tools.

Examining Culturally-Relevant Causal Factors in Evolution Acceptance.

Jamie L Jensen (Brigham Young University)*; Jessica Abele (Brigham Young University); Dalton Bourne (Brigham Young University); Noah Emery (Brigham Young University); Daniel G Ferguson (Texas State University); Kenneth Harrington (Brigham Young University); Jonathan Hodson (Brigham Young University); Grant Rousseau (Brigham Young University)

Abstract:
Study context: It has now been established that religious culturally competent strategies for evolution education (ReCCEE, Barnes & Brownell, 2017) can be successful. Although some of the factors that influence acceptance have been studied, including religiosity (Glaze & Goldston, 2015; Rissler, et al., 2014), perceived conflict (Barnes et al., 2021), understanding the nature of science (Glaze & Goldston, 2015), and knowledge of evolution (see Dunk et al., 2017), the nuances of such factors and their causal relevance to changing attitudes is not well understood. In this presentation, we will highlight two studies utilizing both nationwide survey data and classroom interventions that specifically analyze two causal factors that influence the acceptance of evolution among religious audiences: biblical literalism and culturally-motivated cognition.

Based on the theory of Cognitive Dissonance (Festinger, 1957) that leads to Identity-Protective Cognition (Kahan et al., 2007), we hypothesized that a rejection of evolution by Christian students is less about their understanding of evolution or their scientific reasoning ability, and more about the influence of their Christian worldview on their willingness to engage in evolutionary ideas, or even to admit their own knowledge for fear of betraying their “in group”. Thus, we predict that the relationship between evolution knowledge and evolution acceptance will be dependent upon worldview factors, specifically biblical literalism and culturally-motivated cognition.

Study Design: To test our hypotheses, we conducted both a nationwide sampling study and follow-up classroom interventions. Nationwide study: using the Qualtrics® surveying platform, we sampled 408 individuals who identified as being affiliated with a Judeo-Christian religion, and 421 individuals who identified as agnostic or atheist. Respondents were representative of the US population by other demographic measures. We assessed the following latent variables: knowledge of evolution, acceptance of evolution (micro, macro, and human), religiosity, and biblical interpretation (for theist respondents only). Classroom interventions: To follow-up on biblical literalism as a causal factor, we ran a classroom intervention in which we
taught a culturally-competent “reconciliation” lesson where we discuss the nature of science and the cultural history of the conflict emphasizing potential compatibility between evolution and religious belief. To follow-up on the cultural cognition hypothesis, we gave the knowledge instrument in a modified format that decreased identity-protective responses to a classroom of students and compared this to another classroom that was given the non-modified instrument.

Analysis & Interpretation: Statistics: We analyzed data using structural equation modeling (SEM) as well as linear regression and simple t-test comparisons. Results: (1) Regarding our first hypothesized factor (biblical literalism), SEM on nationwide data and classroom data both showed that among religious respondents, religiosity positively influences biblical literalism, which in turn negatively influences evolution acceptance. A classroom intervention using culturally-competent instruction focusing on potential compatibility showed a decrease in biblical literalism, which predicted an increase in evolution acceptance. (2) Regarding our second hypothesized factor (culturally-motivated cognition), SEM on nationwide data showed a positive relationship between evolution knowledge and acceptance in both religious and non-religious respondents. Additionally, religious respondents had lower evolution acceptance across the board. Our classroom intervention showed, however, that if you revise the knowledge instrument to reduce identity protective cognition by simply adding “According to Science” in front of each statement, students showed higher levels of evolution knowledge, despite equal levels of acceptance, suggesting that students purposefully misrepresent their knowledge to avoid a conflict with their religious identity.

Contribution: The relationship between knowledge and acceptance of evolution continues to be debated in the literature. This study contributes a piece to that puzzle by suggesting that cultural cognition may be playing a role in the relationship. Additionally, this study contributes to our understanding of how to best utilize cultural competence to teach evolutionary theory to religious audiences.

Can non-religious instructors decrease perceived conflict between religion and evolution? A randomized controlled study.

Elizabeth Barnes (Middle Tennessee State University)*; Rahmi Q Aini (Middle Tennessee State University ); Baylee A Edwards (Arizona State University)

Abstract: Study context: Evolution is foundational to biology and yet controversial among students, often due to a perceived conflict with religion (Barnes et al., 2021). Experts recommend the use of conflict reducing practices (CRPs) to reduce perceived conflict with religion and increase acceptance of evolution (Aini et al., 2022; Lindsay et al., 2019). CRPs include a diversity of practices meant to highlight potential compatibility between evolution and religion such as discussing the spectrum of views on evolution and religion, teaching the nature of science as bounded to studying measurable phenomena, and highlighting examples of religious scientists who accept evolution. However, studies often use Christian instructors to implement CRPs when in reality, most biologists likely to teach evolution are not religious (Ecklund & Scheitle, 2007). Will students respond to CRPs differentially if they are implemented by a non-religious instructor? In this study, we tested the efficacy of CRPs when students received them from an instructor who revealed themselves as non-religious or Christian.

Study design: We conducted a randomized controlled trial to test the efficacy evolution instruction with CRPs from a Christian instructor against the same instruction with a non-religious instructor. Introductory biology students (n= 2,625) from 18 courses across 9 states
were randomly assigned to watch one of three evolution instruction videos made by the same instructor actor. They received a video that (1) included CRPs from the instructor when revealing themselves as Christian (n = 863), (2) included CRPs from the instructor when revealing themselves as non-religious (n = 871), or (3) a control video with no CRPs (n = 891). Students completed previously published surveys on their perceived conflict and their acceptance of evolution before and after watching their assigned video. As the last question on the post survey, students reported their religious affiliation.

Analyses and results: We compared student outcomes across the three conditions using hierarchical linear modeling with course as a random effect. First, we found that compared to the control condition, both videos that implemented CRPs led to a greater reduction of conflict and a greater acceptance of evolution. Encouragingly, we also found that CRPs were effective regardless of whether the instructor revealed themselves as Christian or non-religious. However, the non-religious instructor video had a pronounced effect on reducing perceived conflict between religion and evolution among students who identified as atheists.

Contribution: In the first randomized controlled trial testing CRPs in evolution education, we show the efficacy of these practices, verifying that recommendations to use these practices are robust. Further, these data suggest that non-religious instructors can have a positive impact on their religious students but can have a disproportionate impact on their atheist students, which may contribute to increasing atheist students’ ability to effectively communicate about evolution to religious audiences in the future.

Concurrent Short Talks - Session 2

Session 2_A

What student struggles do instructors see? Teacher noticing in course-based undergraduate research experiences.

Alexandra Cooper (University of Georgia)*; Marie Delcy (University of Georgia); Erin Dolan (University of Georgia)

Abstract:
STUDY CONTEXT: Course-based undergraduate research experiences (CUREs) have increased access to research for all students and provided opportunities for more students to engage with science practices and make novel scientific contributions (Auchincloss et al., 2014; Brownell et al., 2012). However, the community has only begun investigating how instructors implement CUREs (Goodwin et al., 2022 & Goodwin et al., 2023). CURE instruction is complex; instructors have to balance being both a teacher and research mentor (Shortlidge et al., 2016; Goodwin et al., 2021). This requires instructors to respond flexibly and responsively, adapting their teaching actions to meet the needs of individual students and their scientific inquiries (Hammer et al., 2012; Feldman et al., 2008; Gafney, 2005; Cooper et al., 2022; Cooper & Bolger, 2023). We argue that an important prerequisite to responsive instruction is noticing student thinking (van Es & Sherin, 2002 & 2006). In other words, implementation of instruction should center around student thinking and challenges, which the instructor must notice. This study presents the first qualitative investigation of instructor noticing in CUREs, providing insight into what instructors recognize and think about student struggles during research.
STUDY DESIGN: To investigate CURE instructor noticing, we asked: What CURE-specific challenges do instructors notice students face in their classrooms? We recruited instructors through general calls to the CURE community through established CURE programs and CURE-related networks. As we sought to build an initial model of instructor noticing in CUREs, we chose to focus our design on measuring more experienced CURE instructors who were currently teaching a CURE and had taught their CURE for a minimum of three semesters. We chose to focus on experienced instructors as previous work has detailed the ways expert instructors see more meaningful patterns in student thinking compared to novice instructors (Berliner, 1994; Furlong & Maynard, 1995; van Es & Sherin, 2008; Levin et al., 2009). Experienced CURE instructors were invited to complete a written survey where they reported on the student challenges they noticed in their CUREs. Of the 60 survey responses, 38 instructors met the eligibility criteria and were included in subsequent analysis. A subset of these instructors participated in follow-up, semi-structured interviews (n=6). Interviews were designed to learn more about the different student challenges reported in the surveys.

ANALYSES AND INTERPRETATIONS: Survey responses were analyzed using an inductive, grounded theory approach, allowing for themes to emerge from data (Glaser & Strauss, 1967; Kearney, 2001; Charmaz, 2014). Although themes emerged from the data, our thinking about the data was guided by our views of science practices (Ford, 2008; Wong & Hodson, 2009), student-identified CURE challenges (Gin et al., 2018; Corwin et al., 2022), and classroom research mentoring (Cooper & Bolger, 2023). Our coding process relied on refining proposed themes by engaging in multiple rounds of content analysis and consensus-reaching discussion by three independent researchers. The final themes revealed that instructors noticed student difficulties navigating the practice of research, the nature of science, and attitudinal demands of research. Regarding the practice of research, instructors noticed that students struggled with executing different scientific practices, connecting science content to their research, and conducting technical aspects of the research. Regarding the nature of science, instructors noticed that students struggled with failed experiments, unexpected or uncertain results, and the lack of structure inherent to research. Instructors described noticing how students’ emotions, motivation, and interest were in response to the difficulties they faced with the nature and practice of research. Thus, we predict student emotions, motivation, and interest may be important cues to instructors when making in-the-moment decisions.

CONTRIBUTION: This study is the first to characterize CURE instructor noticing. As the ability to adapt instruction in the moment relies on what teachers notice, we anticipate these results will be useful for future investigations around instructor decision making and reasoning. Additionally, these findings provide a useful tool for training future CURE instructors. For example, instructors could reflect on the pedagogical strategies they might use when they encounter the different student challenges. Finally, our investigation builds on current work describing CURE student challenges (Corwin et al., 2022), but from the instructor’s perspective.

Development of Learning Outcomes for Non-Major Introductory Biology Using a Delphi Method.

Peggy Brickman (University of Georgia)*; Cara L Gormally (Gallaudet University)

Abstract:
Study Context: Our main study goal was to develop a set of learning objectives (LOs) that support broader course goals consistent with recommendations from Vision & Change for the 8 out of 10 undergraduates who are not science majors. In addition, we performed an online
modified-Delphi study to confirm that our LOs support content acquisition through the lens of socioscientific issues and provide instructors latitude to select specific socioscientific issues and the associated LOs that are of most interest for their courses.

Research Design: 244 instructors of non-majors introductory biology in the U.S. were contacted to identify our panel of experts. Potential participants were identified from numerous sources, including: a prior study of syllabi; BioInteractive Higher Ed Newsletter Subscribers; the Partnership for Undergraduate Life Sciences Education community; SABER; a list of biology faculty from HBCU and tribal colleges; and the American Society for Cell Biology Education Group. We engaged a total of 38 biology faculty experts from institutions across the US in three iterative rounds to identify, rate, discuss, and re-rate >300 LOs for non-majors biology courses to determine whether the LOs are critical for students to learn and if the LOs encompass what students need to learn about this issue, as well as if anything is missing.

The process was divided into two broad phases: a development phase and an evaluation phase similar to Hennessey and Freeman, 2024). During the development phase, candidate LOs went through multiple rounds of evaluation and revision. In total, there were three different groups of researcher-instructors that participated in the development phase and another Delphi group that participated in 2 rounds of review during the evaluation phase. Each group involved different teams of evaluators, all of whom shared instructional expertise in life sciences content and experience with biology education research:

Group 1 consisted of the authors who drafted an initial set of LOs designed to align with issues identified in an analysis of syllabi collected nationally which were also compared to a set of LOs developed for introductory biology courses designed for biology majors (Hennessey and Freeman, 2024).

Group 2 was composed of 5 educators who teach non-majors Biology and regularly advise the BioInteractive program at the Howard Hughes Medical Institute (HHMI) on curriculum development.

Group 3 consisted of two experts with extensive experience in writing LOs and in assessment design.

Group 4 consisted of 27 expert Delphi panelists who provided feedback during three rounds of surveys.

Analyses and Interpretation: The candidate LOs that emerged from the evaluation phase (N=318) underwent two rounds of review (Groups 2 & 3) to determine if the reviewers felt that the LO was clear, was useful for student learning about this issue, and was at the appropriate difficulty level for non-majors taking an introductory course. Codes were developed to characterize comments left by Group 2 and Group 3 and all comments were coded to agreement (authors). After each round of review, the two authors discussed feedback until reaching agreement for each suggested revision. Many revisions involved condensing or removing inappropriate LOs or moving LOs specific to one issue into another unit. In total, each LO went through two rounds of revision during the study’s development phase.

The 270 candidate LOs shared with our final group 4 Delphi experts were characterized for being critical or not for non-majors students. Across all content areas, faculty rated both HOCS and LOCS LOs as critical for student learning, rating at least one third as critical. Although survey participants were unaware of the LOCS or HOCS designation for the candidate LOs they evaluated, we found in interesting that unlike Hennessey and Freeman, we did not see evidence that evaluators were less likely to rate an LO as essential if it represented a lower-order cognitive skill, and much more likely to rate an LO as non-essential if it represented a...
higher-order cognitive skill.

In the final round of review, our Dephi panelists were provided with individual google sheets that included a list of candidate LOs that had >70% agreement as critical (N = 166). We separately binned the LOs that reviewers provided lower agreement (N = 104) for whether they were critical or not. For each LO, we asked the reviewers to: (1) indicate if they thought the LO should be included in our final set of official LOs for non-major’s biology and (2) explain their reasoning. Finally, we provided panelists with a list of 32 LOs that were suggested as missing on the survey.

Contribution: Our research contributes to the development of resources for instructors of introductory biology for non-majors and contributes to an understanding of how faculty prioritize socioscientific issues and basic competencies in non-majors classes.

How Administration Stakes Impact Student Behaviors During Concept Assessments.

Tiffany Burgess (University of Nebraska-Lincoln)*; Crystal Uminski (Rochester Institute of Technology); Brian Couch (University of Nebraska-Lincoln)

Abstract:
STUDY CONTEXT: A prerequisite for bolstering course and program improvement is knowing what students know. One way this is accomplished is with concept assessments. Concept assessments provide a way for instructors to gauge students’ conceptual understanding of material taught in their courses. Unfortunately, instructors may experience constraints surrounding the practicality of administering concept assessments. Such constraints include questions about how to administer the assessment, lack of content applicability to individual courses (scope), and competing demands on instructional time (Madsen et al., 2016). The administration of concept assessments in an out-of-class setting can help to mitigate these constraints and increase feasibility, but the extent to which students consult external resources for assistance is unknown. Prior research comparing different administration conditions explored connections between the amount of time students spend on an assessment and their assessment score, but cautioned that out-of-class scores may also reflect external resource use (Uminski et al., 2023). Our study seeks to better understand how students engage with outside resources when taking a concept assessment under two out-of-class conditions (low-stakes versus high-stakes). We draw on assessment validity theory (Messick, 1987, 1989) to explain the relationships between resource use, completion time, and assessment scores.

STUDY/RESEARCH DESIGN: To understand how different out-of-class conditions affect behaviors and to clarify the potential use of external resources, we administered the Introductory Molecular and Cell Biology Assessment (IMCA) to 458 undergraduate students over 2 years. Students were graded based on correctness (higher-stakes) or participation (lower-stakes) and were asked to only use the information in their heads and to not consult their peers or any other external resources. Upon completion of the assessment, students were given an open-ended prompt to describe how they completed the questions and closed-ended prompts to identify particular actions they used while working on the questions.

ANALYSES AND INTERPRETATIONS: Open-ended and closed-ended survey responses revealed a variety of resource types as well as usage frequency. In an out-of-class setting under higher-stakes, the average IMCA score was 71% versus students under lower-stakes, where the average score was 60%. Additional findings suggested that the use of external resources doubled under higher-stakes and this increased resource use can help explain the
CONTRIBUTION: This study gives insight into the validity of assessment results in an out-of-class environment, under lower-stakes and higher-stakes conditions and tells us more about the extent to which these results reflect student knowledge. Through an enhanced characterization of the ways students utilize external resources on concept assessments, instructors may make more nuanced interpretations regarding student conceptual understanding. This study aims to contribute to teaching and learning by informing the implementation of concept assessments under conditions that do not impede on limited instructional time.

Exploring Tones, Trends, and Tales in the Syllabi of Undergraduate Biology Courses.

Ania Majewska (The University of Georgia)*; Areeb Khan (The University of Georgia); Robert Richards (Georgia Tech); Chioma Anyanwoke (The University of Georgia)

Abstract

Syllabi, being the initial documents students receive in a college course, serve as crucial sources of information concerning covered topics, instructor contact details, and grading and attendance policies (Gin et al., 2021). How instructors communicate this information is important in conveying the classroom environment and culture. Indeed, past studies indicate that non-content language can be important for student engagement, success, and learning (Harrison et al., 2019). In this study, we examined the content of syllabi for undergraduate biology courses. We aimed to answer two main questions: (1) what tones are present in syllabi, and (2) are there differences in metrics between subdisciplines, upper and lower-level, small and large enrollment courses, as well as instructors. To answer these questions, we extracted information from over 350 biology course syllabi from a large R1 institution from the southeast, including year, semester, course level, grade distribution, grading policy, attendance policy, and diversity statement. In addition, we used freely available data to add instructor rank and class size. We used Grammarly to acquire tone and natural language processing toolkits to characterize and analyze the language used in syllabi. Our final dataset includes 400 variables that characterize the syllabi from 2006 to 2022. We used comparative statistics and mixed-effects models to analyze the data. Findings suggest a difference between subdisciplines in the proportion of grades that depend on exams. We also noted a general decline over time in the emphasis on exams and a shift towards other assessments. Diversity statements were found in 9 syllabi and did not appear prior to 2020. We found that syllabi have increased in the number of words over time. Interestingly, we found that as class size increased, the word count of attendance policies decreased for lower division courses compared to upper division courses. We noted some interesting differences between syllabi of tenure-track compared to non-tenure track instructors: tenure-track faculty had significantly shorter attendance policies and a higher proportion of grades determined by exams. The most common tones in attendance and grading policies detected by Grammarly included “formal”, “informative”, and “direct”; however, full professors showed greater variation in tones compared to other instructor ranks. The results of this work elucidate the ‘evolution’ of biology syllabi, differences in syllabi based on instructor rank, and the underlying messages these important documents can convey.

Gin et al. 2021. It’s in the syllabus… or is it? How biology syllabi can serve as communication tools for creating inclusive classrooms at a large-enrollment research institution. Advances in physiology education.

Harrison et al. 2019. Investigating instructor talk in novel contexts: Widespread use,
unexpected categories, and an emergent sampling strategy. CBE—Life Sciences Education 18:ar47

Make it personal: Individualizing post-exam encouragement increases future exam scores for undergraduate genetics students.

Hannah Jordt (University of Washington)*; Quila Welch (University of Washington)*;

Abstract:
Study Context: Strong, positive, undergraduate-faculty relationships can lead to increased student performance, self-efficacy, motivation, and other metrics (Chemosit & Rugutt, 2020, Komarraju et al, 2010, Ayllón et al, 2019). Yet while it is clear that personal interactions can facilitate these types of relationships, specific strategies for connecting with undergraduates in a classroom setting have rarely been tested experimentally for effectiveness (Hagenauer & Volet, 2014).

Study Design: In a randomized classroom experiment, we explored whether an encouraging email containing advice from the course instructor after the first exam in a large-enrollment, introductory genetics class had a greater impact on a student's subsequent exam score if the message was personally addressed to the student. We hypothesized that this personalization would lead to increased scores on the following exam compared to students who received an almost identical email that was instead addressed to the entire class.

Analyses & Interpretation: We used multiple linear regression to control for student-level characteristics, including prior academic performance, gender, race, first-generation college student status, and international student status. Our models indicated that, on average, students receiving the personalized email performed 11.34% better on their following exam compared to students who received the same encouragement and advice without the personalization (p < 0.001). Furthermore, the intervention impacted students from different demographic groups equally, with the exception of Asian American students from majority Asian populations, who were not impacted by the intervention.

Contribution: This dramatic result suggests that a simple check-in from an instructor can have a significant impact on undergraduate learning gains, as long as the interaction is directed towards them personally. It also provides an evidence-based, effective, and easily implementable strategy for facilitating positive teacher-student relationships in a large-enrollment college STEM classroom.

Session 2_B

Fostering Meaningful Research: Examining How Students Connect to Broader Contexts in CUREs.

Lily R Dodge (University of Minnesota); Dhanya Attipetty (University of Minnesota)*; Catherine Kirkpatrick (University of Minnesota); Anita Schuchardt (University of Minnesota)

Abstract:
CONTEXT:
Course-based undergraduate research experiences (CUREs) have been implemented to improve undergraduate student access to authentic research and differ from traditional
laboratory classes by situating research experiences within a broader context (BC; Auchincloss et al., 2014). BCs refer to any context beyond the classroom, such as a community setting, real world problem, or scientific field—a key value of the Culture of Scientific Research Framework (Authors, 2021). CUREs encompass many fields of research and are formatted as either wet labs (WLs) or computer-based labs (CBLs), which have different constraints and affordances (Authors, 2019). Most research on CUREs has focused on student learning outcomes (Dolan, 2016). There is limited research on how students connect their projects to a BC within various CURE contexts and formats. Evaluating student connections across formats and contexts will inform the design of future CUREs.

RESEARCH QUESTION:
How does the format and context of a CURE impact students’ ability to connect their projects to a broader context?

STUDY DESIGN:
Undergraduate biology majors in their second semester of a required CURE at an R1 university gave poster presentations at the end of the semester, which were recorded and transcribed. Students designed and conducted their CURE projects to study 3 different contexts: Evolution (WL (EWL): E. coli, Sp22, n=10 & CBL (ECBL): Avida-ED computer program, F21, n=10), Microbiomes (WL (MWL): zebrafish, Sp18, n=6 & Microbiome CBL (MCBL): online dataset, Sp18, n=9), or Toxicology (WL (TWL): zebrafish, Sp18, n=6), which all had the same structure. In this qualitative study, a random subset of recordings were coded using a codebook developed from transcripts and literature. Additional coding is in progress. Introductions of student presentations were coded for whether they included background information connected to a BC (IBC). Conclusions were coded for whether students analyzed data within classroom knowledge (CC) or situated their findings in a BC (CBC). Future directions were coded for whether students remained within classroom capabilities (FDC) or situated their ideas within a BC (FDBC). (93% agreement, 2 independent coders, 37% of transcripts).

ANALYSES & INTERPRETATIONS:
Preliminary data shows that over 90% of students across all CURE formats and contexts include BC when introducing their projects (Table 1). One MWL group stated: “The widespread use of antibiotics has caused a lot of antibiotic resistance in the world, and overused antibiotics can exacerbate and increase the frequency of intestinal disorders,” illustrating how the student situates their gut microbiome project using the problem of antibiotic resistance in medicine as their BC.

Table 1: Proportion of presentations that connected to BCs by research context.

<table>
<thead>
<tr>
<th>Research Context</th>
<th>EWL</th>
<th>ECBL</th>
<th>MWL</th>
<th>MCBL</th>
<th>TWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>.9</td>
<td>.9</td>
<td>1</td>
<td>.9</td>
<td>1</td>
</tr>
<tr>
<td>Conclusion</td>
<td>.4</td>
<td>.4</td>
<td>.3</td>
<td>.4</td>
<td>.7</td>
</tr>
<tr>
<td>Future Direction</td>
<td>.4</td>
<td>.5</td>
<td>.5</td>
<td>.7</td>
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</table>

In contrast, less than 50% of students in all contexts except TWL included BC in their conclusion (Table 1). One example of CBC from an ECBL group was: “This would mean that if an invasive species came in and competed with the native populations, it could result in a decrease of those specialized adaptations.” The student used the BC of ecology when analyzing their findings. Students who included CC in their conclusions tended to attribute their results to human error or statistical significance.
In future directions, under 50% of groups in all contexts except MCBL and TWL referred to a BC (Table 1). One TWL group said, “we’re thinking of applying the effects of triclosan to different organ systems like neurological systems,” which indicated they were suggesting taking their future project outside of classroom capabilities and applying it to the BC of neuroscience. In contrast, an EWL group restricted their discussion of future directions to a classroom context, repeating the same experiment by “add[ing] more trials [with various antibiotic concentrations] just to get results that are more accurate.”

Overall, independent of CURE context or format, students tended to connect their introductions to a BC but struggled to connect their analyses and future directions to the BC of their study.

CONTRIBUTION:
Although past research on CUREs has focused on student learning outcomes, this study adds to literature by exploring how students connect their work to a BC, a key characteristic of scientific research and CUREs (Auchincloss et al, 2014; Authors, 2021). Preliminary data suggests that more explicit instruction may be needed to foster students’ ability to connect CURE projects to a BC in the conclusions and future directions of their presentations, allowing for more authentic work. Future research on the quality and nature of student connections to BCs across CURE formats and contexts can lead to the development of more meaningful CURE curricula.

Investigating student noticing of quantitative reasoning in introductory biology labs.

Jeremy Hsu (Chapman University)*; Sara Gartland (University of Delaware); Joelle Prate (Chapman University); Charles Hohensee (University of Delaware)

Abstract:
STUDY CONTEXT: Quantitative reasoning (QR) represents a key skill for undergraduate biology education. Despite its importance, however, QR remains a challenge for many students, and there remain limited empirical studies on how undergraduate students learn QR skills in the context of biology courses. Previous work has focused on creating instruments that measure QR skills in the context of biology (Stanhope et al. 2017) or on developing and assessing specific curriculum that promotes students’ QR skills in biology (e.g., Hester et al. 2014; Hoffman et al. 2016; Thompson et al. 2010). In addition, there have been a number of recent studies examining students’ sensemaking – i.e., how students conceptually organize and draw meaning from a given topic – when working with mathematical equations in biological contexts (Kalderas & Wieman 2023; Zhao et al. 2021; Zhao & Schuchardt 2021). Here, we use the theoretical framework of student noticing to investigate why some students struggle with QR in introductory biology labs. This framework has been used to understand how students learn new concepts, primarily in K-12 math education (Hohensee, 2014, 2016; Jones et al. 2023; Lobato et al. 2012). Under this framework, what students notice when given new information and data influences how they process this information and connect it with other events to form new conceptions (Dominguez, 2016; Hohensee, 2016; Lobato, Hohensee, & Rhodehamel, 2013; Wilkie, 2022). Students must mentally isolate given features, create mental records of those features, and then identify features or objects that they connect to existing knowledge (Hohensee, 2016; Lobato et al., 2012). Identifying these features or objects is thus critical since they form the foundation upon which learning take place (Hohensee, 2016).

RESEARCH DESIGN: We had three research questions:
1. What are students noticing when working with and analyzing their own quantitative data in introductory biology labs? How do students reflect on and characterize their noticing?
2. Are there differences in students’ level/depth of noticing, including how much they notice, when working with quantitative data?
3. What factors influence students’ depths of noticing when working with quantitative data in biology labs?

We conducted running record observations (Poulson et al. 1995) of nine groups working with quantitative data in an introductory biology lab. Students (n=33) were interviewed afterward, with questions designed to probe what they noticed during lab and the factors that influenced their noticing. We utilized stimulated recall (Calderhead 1981) to further probe students’ noticing. Interviews were transcribed and analyzed through thematic analysis (Braun and Clarke 2012). In brief, multiple authors independently read >10% of interviews and came up with independent codebooks; the authors then created a consensus codebook through iterative discussion. To ensure validity and reliability, we utilized a constant comparison approach (Glaser 1965) where one author would code an interview and compare to the existing codebook before discussing with the other authors.

ANALYSES AND INTERPRETATIONS: Our phenomenological analyses reveal variation in what students notice as well as the depth of their noticing. We identify three conceptions of student noticing: 1) students who are not noticing any relevant feature during the labs (“not noticing”), 2) students who notice shallower features largely related to lab procedures and instruction (“shallow noticing”), and 3) students who notice deeper conceptual features that connect biological concepts with QR (“deep noticing”). We identify multiple aspects that vary within these conceptions. For example, students at the not noticing and procedural noticing levels tended to have lower self-efficacy for both biology and math and viewed math and biology as distinct disciplines, while those at the deep noticing level saw greater utility and connections between math and biology when doing QR. Similarly, we identify variation in the aspects that influence what students notice and their level of noticing. These include multiple cognitive and affective factors that shaped students’ noticing, including their level of metacognition and motivation for completing the labs.

CONTRIBUTION: Our study offers a first look at how students learn QR in intro bio labs, providing insight into what students are noticing when working with QR in bio labs, and how they begin to make sense of quantitative data. Our results reveal different conceptions of student noticing with multiple aspects that vary, suggesting that targeted interventions that influence any of the aspects that vary may guide students to notice deeper, conceptual themes when working with QR. Our work is thus of interest to both biology education researchers and practitioners since it offers new knowledge on the theoretical underpinnings of learning QR and can inform instruction on QR in biology labs.

Participation in primary literature critique opens opportunities for undergraduate biology majors’ recognition of themselves as epistemic agents.

Gabrielle Jablonski; Anna Grinath (Idaho State University)*

Abstract:
Study Context: When students routinely participate in science practices, they learn not only what we know in science but how we know it (Duschl, 2008). Such experiences are important for deep knowledge development and also position students as knowers, doers, and shapers of science – or epistemic agents (Stroupe, 2023). Ultimately, the ways students are positioned
and recognized as epistemic agents in science by teachers, peers, and self can expand (or restrict) how they see themselves because identities shift and solidify through the mechanisms of recognition and positioning (Gresalfi & Hand, 2019). Despite these tight theoretical connections, research is needed to describe how participation in science supports students’ identity-work in practice. Our study addresses this need by examining how participating in critique during structured discussions of primary literature articles opened opportunities for undergraduate biology majors’ recognition of themselves as epistemic agents in science.

Research Design: We conducted a longitudinal multi-case study at a 4-year university. We identified two contexts with explicit opportunities for biology majors to critique primary literature that were designed by the same professor: 1) a 10-week summer journal club; 2) an upper-division Entomology course with 10 weekly primary literature discussions. We used stratified purposeful sampling to select two cases from Journal Club (Dylan & Hayden) and two cases from Entomology (Jillian & Fiona). Semi-structured interviews were conducted at the beginning and end of the semester to capture longitudinal aspects of recognition work. The interviews elicited students’ descriptions of their participation in primary literature discussions, their meanings of critique and the purpose of this practice for them, their perceptions of themselves as a scientist, and their perceptions of others.

Analyses and Interpretations: We conducted thematic analysis to code the transcribed interviews for instances of recognition work using markers from our theoretical framework (e.g., ways participants felt they could participate, how they saw themselves and for what reasons, how they were positioned by others). Initially, the ways students recognized their authority constrained how they felt they could contribute through critique. Participants did not recognize themselves as able to critique due to their status as undergraduate students:

"I think there's something about being an undergraduate. That is like you, you don't know yet. It's like, I don't have the authority to be critical yet if that makes sense. It's being a little presumptuous almost to think that I would know better than someone who just published an article, you know what I mean?" [Hayden]

Through regular participation in primary literature critique, participants expanded their meanings of critique, which promoted recognition work. Participants described that their association of critique with criticism loosened over the semester and they realized the role of both positive and negative critiques:

"There's destructive criticism where you're tearing something down and there's constructive criticism where you're building something up. And I think that in life, in general, and in things we assess, like the primary literature, there needs to be a balance of both." [Jillian]

Participants’ meanings of authority also expanded to recognize that their prior experiences gave them unique insights to contribute, which was significant for their recognition work:

"Sometimes I felt like I just did not know enough about the subject to make a valid critique. And I think that can be true. But also, it always seems like, you know, you’re coming to the paper with your whole set of experiences and the way you’re interpreting this paper is going to be so much different than the next person. And I find a lot of value in that because you can develop unique critiques based on your experience, and I think I'm getting more comfortable with that." [Fiona]

These findings illustrate how regular participation in the practice of critique during structured
primary literature discussions allowed undergraduate biology majors to expand their initial understandings of critique as a scientific practice and recognize their own authority and epistemic agency to critique scientific claims.

Contribution: These findings have educational implications for designing primary literature discussions to encourage recognition work. Article discussions are a common activity in undergraduate biology classrooms and our research suggests that they provide critical opportunities to position and recognize students as epistemic agents in the biology community. Such opportunities can be intentionally elevated if faculty explicitly highlight the variety of productive ways their students can (and do) participate in critique so that each student may find their entry point to participate in critique as a science practice.

Lab Talk: Does non-content instructor talk explain effectiveness of CUREs? C.J. Zajic (University of Georgia)*;

Jeffrey T. Olimpo (The University of Texas at El Paso); Kelly Subramanian (UC Davis); Benjamin Listyg (University of Georgia); Erin Dolan (University of Georgia)

Abstract:
Study Context
Course-based undergraduate research experiences (CUREs) provide opportunities for a greater number and diversity of students to engage in scientific research (Auchincloss et al., 2014; Bangera & Brownell, 2014; Gentile et al., 2017). Additionally, CUREs have been shown to promote student benefits, such as increased retention in college and in science majors and enhanced integration into the scientific community (Hanauer et al., 2017; Rodenbusch et al., 2016). However, less is known about the underlying mechanisms that make CUREs effective for students. Here we investigated whether CURE instructors talk to their students in ways that are distinctive from non-CURE lab courses. Specifically, we examined the types of questions instructors ask (McNeill & Pimentel, 2010), the mentoring support instructors provide (Eby et al. 2013), and the extent to which instructors engage in non-content talk (Seidel et al. 2015). Furthermore, we determined the extent to which these types of talk are associated with indicators of integration into the scientific community (Estrada et al. 2011) and the values and costs that students associate with continuing to do research ((Barron & Hulleman, 2015; Wigfield & Eccles, 2000).

Study Design
With this study, we aimed to address two primary research questions:
1. What forms of instructor talk, if any, are unique to CUREs?
2. To what extent are patterns of instructor talk related to students' scientific integration and perceptions of the benefits and costs of doing research?
We collected class recordings from 50 instructors teaching 48 unique introductory life science laboratory courses at 39 different institutions. Of the 48 courses in our final sample, 22 included research (i.e., CUREs) and 26 included no research (i.e., non-CUREs). Recordings were collected across multiple days of class, resulting in a total of 135 to 739 minutes (M=406 minutes, SD=163 minutes) of recording for each instructor in our final analytic sample. We also surveyed students (N=476) at the beginning and end of these courses about indicators of their scientific integration (i.e., scientific self-efficacy, scientific identity, and graduate and career intentions) and their perceptions of benefits and costs of research. We also surveyed students at the end of their courses about the degree to which they had rapport with their instructor, had opportunities to make relevant discoveries and engage in iterative work, and the extent to which they developed a sense of ownership of their work.
Analyses & Interpretations
To answer our first research question, we performed qualitative content analysis to identify and define distinct forms of non-content instructor talk in introductory life science laboratory courses. We used a combination of inductive and deductive coding. Each transcript was coded to consensus by at least three members of the research team. After coding was complete, we normalized the counts of each talk type by the total minutes of recorded class time for each instructor. This allowed us to compare the non-content instructor talk employed by instructors in CURE and non-CURE courses. We found that specific forms of non-content instructor talk were more prevalent in CUREs, such as instructors discussing the nature of science with their students. Other forms of talk were not distinctive, such as instructors providing students encouragement in their lab work. To answer our second research question, we first tested whether student reports of opportunities to make relevant discoveries, engage in iterative work, and develop project ownership related to the number of research weeks in their course. We found that student reports of discovery and iteration, but not ownership, positively related to research weeks. Then, we fit a series of linear mixed effects models with instructor talk types and research weeks as predictors of students’ post-course scientific self-efficacy, scientific identity, career intentions, and benefit and cost perceptions, controlling for pre-course levels of each variable of interest. Although analyses are still in progress, results thus far indicate instructor talk types positively relate to student ratings of their rapport with their instructor. Furthermore, research weeks predicts students’ scientific self-efficacy gains, but instructor talk does not.

Contribution
This work has implications for research and instruction. Our findings suggest that instructor talk is important for building student-instructor rapport but does not appear to be a causal factor in CURE effectiveness even though particular types of talk are more evident in CUREs than non-CUREs. Thus, the design features of CUREs that foster scientific integration remain elusive; future research should aim to investigate other potentially distinctive aspects of CURE instruction. Our work also highlights the value of connecting instructor variables with student variables to develop novel educational insights.

What do you remember from first year biology? An investigation of student knowledge retention using two-stage examinations. Cassandra Debets (University of Manitoba)*; Abby Judge (University of Manitoba); Kevin G.E Scott (University of Manitoba)

Abstract:
Research questions: Two-stage exams allow for the unique opportunity where students collaborate during examinations and therefore become active participants in their learning journey during examinations. Collaboration during two-stage exams have been shown to improve student learning gains in first year courses (Cooke et al. 2019), upper-level courses (Cortright et al. 2003), multiple choice exams (Leight et al. 2012), and opened ended question exams (Cooke et al. 2019). However, the effects of two-stage exams on knowledge retention remains elusive. Additionally, how knowledge retention impacts knowledge retention at different Bloom’s levels has never been studied. Specifically, our objectives were to:

1) Determine how two-stage exams influences knowledge retention at various Bloom’s levels and

2) Determine student perceptions as well as learning gains made by different cohorts of
students.

Research design: Using a quasi-experimental design, we recruited 160 first year biology students. The students first completed a multiple choice in-class test on the topic osmosis in the two-stage format where only half of the original questions in the individual stage were asked on the group stage. This test created two treatments of questions, individual only questions and group stage questions. Questions from each treatment were then retested on midterm one (5 days later), midterm two (53 days later), and the final exam (85 days later) for evidence of knowledge retention. Retention was assessed by comparing the average score as well as the proportion of students of students who answered questions correctly in the individual only and group stage questions.

Analyses and interpretations: For the in-class test, average scores were significantly higher by 22.94% in the group stage compared to the individual stage (T160 = 6.7, p = < 0.001). Furthermore, our results indicate that group stage questions improve knowledge retention at relatively long time periods. For the reassessment of questions on the final exam (day 85), the average score of the group stage questions performed significantly better than the individual only questions at every Bloom’s level analyzed. Additionally, group stage questions had a higher proportion of students retain the concepts on the final exam compared to individual only questions (X2(1, 160) = 97.8 p < 0.005). Likewise, students were less likely to forget group stage questions on the final exam compared to individual only questions. Our results reveal that group stage exams do not impact specific cohorts of students differently. Survey results reveal that 70% of students agree that two-stage exams help them retain information. Taken together, the data suggests that two-stage exams offer benefits beyond the improvement of student performance.

Contribution: Our results show that two-stage exams in introductory biology courses improves knowledge retention, especially at the apply level in Bloom’s taxonomy. Two-stage exams can be an effective tool to allow students to collaborate with one another, improve learning gains, and improve the retention of concepts. We suggest that, when feasible, instructors exploring new ways to integrate collaboration into their classroom will consider implementing two-stage exams for improved learning gains and knowledge retention.

Session 2_C

Insights from Year 1 and Year 2 of The College Learning Study: How Life Science Students’ Metacognitive Regulation Skills Change Over Time.

Stephanie M Halmo (University of Georgia)*; Olive McKay (University of Georgia); Brandon Reece (University of Georgia); Rayna Carter (University of Georgia); Gheed Nafea (University of Georgia); Julie Dangremond Stanton (University of Georgia)

Abstract:
STUDY CONTEXT: Metacognition, or knowledge and regulation of thinking (Brown, 1978; Jacobs & Paris, 1987), is a strong predictor of learning (Hong et al., 2020). As students matriculate through college, some are still developing their metacognitive skills. While differences in metacognition between first-year and senior life science students have been described from cross-sectional data (Stanton et al., 2019), how metacognition develops longitudinally in the same students has not been thoroughly investigated. Our study focuses on two metacognitive regulation skills: evaluating and monitoring (Schraw, 1998). Evaluating
occurs when a student gauges the effectiveness of their plan for learning after completing a learning task. Monitoring occurs when a student assesses what they do and do not know while learning. The use of metacognition can be affected by learning self-efficacy, or one's belief in their capacity to learn (Bandura, 1997).

RESEARCH DESIGN: We asked the longitudinal research question: How have students’ evaluating and monitoring skills and their learning self-efficacy changed over time? Guided by Schraw’s metacognition framework, we developed and used a semi-structured interview protocol to collect data from 47 students at three different institutions in their first year of college and then again in their second year of college. Interviews were conducted over Zoom and recorded. Recordings were transcribed and checked for accuracy.

ANALYSES & INTERPRETATIONS: We used qualitative holistic analysis to analyze each participant’s use of metacognitive regulation skills and learning self-efficacy at the two timepoints (Year 1 and Year 2). To facilitate analysis, we created a profile template to determine what changed and what stayed the same for each participant over time. Two or three researchers completed a profile for each participant, and then met to discuss the analysis of that participant’s data. After discussion, the research team synthesized a final profile for each participant. This method was essential for making comparisons across participants because our interview dataset was over 2,000 pages in length. We then conducted a secondary thematic analysis of the final profiles to compare changes and similarities in evaluating, monitoring, and learning self-efficacy across all participants (Saldaña, 2021).

Evaluating results: In Year 2 we observed an increase in students comparing their exam grades to their peers’ performance or the overall class average as a way to evaluate their study plan effectiveness. One student commented, “I don't like to compare myself to others and the class average, but sometimes that's the only resource that I have when it comes to understanding, ‘Am I doing well in this course?’” This comparison of performance directly impacted students' confidence in learning. For example, when students scored below the class average, this lowered their confidence in learning. The practice of sharing the class average with students might reinforce competition in STEM, which can be demotivating to some while motivating to others: “I'll overhear someone around me get a better grade than me, and then I'll be like, oh, I'm not letting this person beat me ever again.”

Monitoring results: In Year 2 students shifted from using self-explanation to using peer questions and peer explanations to monitor their understanding of course content. Students described using the questions their peers asked in class or during office hours as an “eyeopener” into what material they did not know and viewed peers’ asking them for explanations during in-class questions as opportunities to monitor their own understanding. Students also monitored in study groups where they determined, “If I can teach it, then I know it.” For some students, group studying boosted their confidence in learning: “helping others and teaching others that I'm in the class with… gives me the confidence that I know what I'm talking about.” Monitoring with peers can help students identify concepts they do not yet know, which they may not be able to recognize when studying by themselves.

CONTRIBUTION: By understanding the changes that occur in how the same students evaluate and monitor from their first year to their second year in college, we have gained insight into how metacognition develops longitudinally. Our results suggest that students in their second year of college have a greater awareness of their peers as they evaluate and monitor their learning, and that this impacts their learning self-efficacy. From these findings, we encourage instructors to: 1) think carefully about when and why they choose to share the class average with students and 2) offer guidance to students on how to maximize monitoring opportunities.
with their peers. This knowledge can be used to help students strengthen their metacognition early in their college careers, which will improve future learning.

**Exploring STEM GTAs' Perceptions of Teaching Autonomy, Pedagogical Discontentment and Self Efficacy.**

Alyssa Freeman (Idaho State University)*; Grant E Gardner (Middle Tennessee State University); Marco Said (Middle Tennessee State University); Beari Jangir (Middle Tennessee State University); Chelsea Rolle (Middle Tennessee State University); Kadence Riggs (Middle Tennessee State University)

Abstract:
Many universities in the United States heavily rely on graduate teaching assistants (GTAs) to teach small laboratory sections associated with large lecture-based introductory science courses. As such, GTAs have a large impact on the learning of undergraduate students and could influence student retention in the STEM disciplines. Prior research has indicated the importance of considering an individual's perceptions to support their use of evidence-based teaching practices. In this study, we were interested in GTAs' self-efficacy (confidence for teaching) and their perceptions of pedagogical discontentment (dissatisfaction with one’s teaching practices). When instructors with high self-efficacy experience pedagogical discontentment, they may attempt new instructional practices, but instructors with low self-efficacy may engage in avoidance behaviors related to instructional change. We were interested in exploring the role autonomy (control over what and how an instructor teaches) has on these variables since GTAs may not develop pedagogical discontentment with limited autonomy. We were also interested in exploring how the relationships between these variables differ among the STEM disciplines.

Specifically, our research questions for this study were: 1) What are STEM GTAs' perceived teaching autonomy, pedagogical discontentment, and self-efficacy? 2) How and to what extent do perceived teaching autonomy and pedagogical discontentment differ among the STEM disciplines? 3) Are there relationships between perceived teaching autonomy, pedagogical discontentment, and self-efficacy, and what explains these relationships? To answer our research questions, we administered cross-sectional surveys to a sample of GTAs in the biology, geology, chemistry, and mathematics disciplines (n = 50). We used the survey results to identify interview participants with high (n = 1), moderate (n = 2), and low (n = 3) perceptions of autonomy to construct case studies of these sub-groups. Qualitative data from interview transcripts were deductively coded using an a priori code book from the literature.

Results for Research Question 1 revealed moderate Likert scale averages of autonomy for the GTAs to decide the content and to select their teaching practices. For each subconstruct of pedagogical discontentment (ability to teach all students, content knowledge, assess student learning, and balance depth versus breadth of instruction), the GTAs reported being between content and very content. This suggests that the GTAs' have limited pedagogical discontentment (satisfaction). For self-efficacy, The GTAs reported being somewhat confident to very confident to create a productive learning environment and to use various instructional strategies.

In response to Research Question 2, there was evidence of a difference in the teaching autonomy of GTAs based on their discipline. The biology and chemistry GTAs reported lower autonomy perceptions than the geology and mathematics GTAs. There was no evidence of a difference in the GTAs' perceptions of pedagogical discontentment among the disciplines. There was, however, evidence of a difference in the GTAs' reported perceptions of self-
efficacy. Biology and mathematics GTAs reported higher self-efficacy perceptions than the chemistry and geology GTAs.

In Response to Research Question 3, we found that GTAs’ perceptions of autonomy, pedagogical discontentment, and self-efficacy were related. For example, one participant was a mathematics GTA who indicated having high perceptions of autonomy on the survey. In his interview, he expressed some pedagogical discontentment with teaching to a departmental final. Overall, this participant felt content and autonomous with his practice. He also felt confident with his teaching, except when students made him feel awkward. He stated, “If my students are all sitting there and they're kind of quiet and sort of hesitant, it's like I pick that vibe up from them, and then I start to feel kind of weird myself.” In these moments, his limited confidence appeared to be influenced by his practices; having students participate in group work (versus lecturing to students) decreased the awkwardness he experienced with students and thus increased his confidence. This participant’s perceptions of autonomy influenced his pedagogical discontentment, while student interactions influenced his self-efficacy. In addition to the quantitative findings for Research Questions 1 and 2, we will report the findings from all interview participants in our presentation.

Due to the crucial role of GTAs, it is essential to learn how to support GTAs in the complex process of using evidence-based teaching practices. In doing so, individual GTAs’ perceptions of autonomy, pedagogical discontentment, and self-efficacy must be considered. Our study has implications for how GTAs’ perceptions could influence their readiness to learn and try new instructional practices.

Testing mindset interventions at two levels improved student outcomes at a Historically Black University.

Anisha Navlekar (Texas Tech University)*; Adreinne Smith (North Carolina Agricultural and Technical State University); Elizabeth A. Canning (Washington State University); Anastasia Chouvalova (Texas Tech University); Kimberly Pigford (North Carolina Agricultural and Technical State University); Lisa B Limeri (Texas Tech University)

Abstract:
Study context: Research suggests that students who are first in their families to attend college, (i.e., first generation) experience academic disparities due to various socio-economic and socio-psychological factors (Canning et al., 2020; Cataldi et al., 2018). These experiential differences often lead to lower academic outcomes, feelings of disconnection from classrooms as well as of being an “imposter,” and increased concern about their ability to persist in scientific careers (Canning et al., 2020; Walton & Brady, 2017). Approaches to combat this inequity include interventions based in psychological theory and research which are easy to implement in classrooms (Canning et al., 2020; Limeri et al., 2020; Yeager et al., 2019). Prior interventions targeting mindset (beliefs about whether intellectual abilities are static or improvable) have increased grades as well as persistence in science for students facing the challenges described above (Aronson et al., 2002; Yeager et al., 2019). Mindset interventions attempt to persuade students that intellectual abilities can be improved (a growth mindset) by having students read articles describing how the brain is malleable and asking students to write messages to future students reinforcing this message. Recent research suggests that these interventions are most effective when students’ social environment supports a growth mindset (Yeager et al., 2019). We test whether simultaneously modifying the context to reinforce growth mindset messages can enhance the effectiveness of mindset interventions. Prior studies have begun exploring the impact of instructor messages encouraging students to seek help and perceive challenges as an opportunity to learn (Canning et al., 2019; Rattan et
al., 2018). The current study examines the effect of these two solutions (mindset interventions directed at the students and instructor growth mindset messaging) individually and in conjunction, on academic and affective outcomes of students attending a Historically Black College and University (HBCU) in the United States.

Study design: We conducted this study over the 2022-2023 academic year in an introductory biology course for non-majors at a large south-eastern HBCU (n = 1800). Students completed a typical mindset intervention activity (involving a reading and writing activity) or a control activity that taught about brain structure. Instructors included a mindset-supportive message in the syllabus and post-exam emails (intervention) or control messages that were generically encouraging and supportive but did not explicitly encourage a growth mindset. We conducted a 2x2 fully crossed experimental design where we randomized students into one of four conditions: received both student and instructor interventions (+, +), student intervention only (+, -), instructor intervention only (-, +), or double control condition (-, -). We surveyed students at the start and end of semesters to assess changes in their personal beliefs about abilities, sense of belonging, imposter feelings, persistence in science, interest in biology, and perception of their instructors’ beliefs about their abilities (Estrada et al., 2011; Hoffman et al., 2002; Knekta et al., 2020; Leary et al., 2000; Limeri et al., 2023). We also obtained their course grades at the end of the semester.

Analyses/Interpretation: Our final dataset included survey responses from 1624 students; 59.5% were continuing generation (previous family member/s attended college) and 37.5% were first generation; the remaining did not provide demographic information. We used hierarchical linear models to determine the impact of the intervention conditions on course grade. We found that assignment grades increased for all students in all the intervention groups (F(1, 1590) = 3.46 p = .008) while exam grades increased for first generation students specifically in the student intervention group (F(8,1543) = 6.45 p = .011). We also found that being in independent intervention conditions increased students’ personal growth mindset beliefs, i.e. their belief that intelligence is malleable (F(8,828) = 2.17 p = .03). Being in independent intervention conditions also led to increased intent to persist in science careers for first generation students (F(8, 832) = 3.77 p = .052) as well as an increased interest in biology (F(8,832) = 1.09 p = .024). No other psychosocial outcomes changed significantly in response to the interventions.

Conclusions: Our results demonstrate that low-cost, scalable mindset interventions at both the student and instructor-level can improve students’ grades and foster beliefs that they can improve their intelligence. Additionally, our results suggest that these interventions are particularly impactful for first generation students’ intent to persist in science fields. Findings from this study inform manners in which instructors can support and encourage their students in cost-effective ways within the classroom.

Factors that influence academic help-seeking in undergraduate biology courses: a social ecological perspective.

Sharday N Ewell (University of Mississippi)*; Ryan D.P. Dunk (Auburn University); Jordan Fluker (Auburn University); Alayna Harvey (Auburn University); Amelia Radocha (Colorado College); Rachel M Youngblood (Auburn University); Audrey C Lew (University of California, Irvine); Shobnom Ferdous (Auburn University); Yohannes Mehari (Auburn University); Ashley Peart (Auburn University); Michael Seibenhener (Auburn University); Cissy Ballen (Auburn University)
Abstract:
STUDY CONTEXT: Academic help-seeking is a learning behavior that allows learners to acquire the content knowledge and skills necessary for academic success and promotes STEM persistence (Micari & Calkins, 2021; Park et al., 2019; Kitsantas & Chow, 2007). To successfully obtain academic help, students must identify the need for help and then interact with others to receive help (Karabenick & Gonida, 2018; Kozanitis et al., 2017). Despite the benefits of help-seeking, most students will recognize that they need help and will not seek it due to individual or contextual barriers (Martin-Arbos et al., 2021). While previous literature (Martin-Arbos et al., 2021; Brown et al., 2020; Kiefer & Shim, 2016; DiBenedetto & Bembenutty, 2013) has focused on the individual effects of contextual or personal factors on academic help-seeking, there is a lack of in-depth literature that holistically examines how contextual, social, and personal factors interact to influence the academic help-seeking processes of undergraduate students enrolled in biology coursework. Given that student behavior is influenced by the complex interactions between personal (e.g., race/ethnicity, self-efficacy, gender, prior experiences), social (e.g., interactions with students and faculty), and contextual (e.g., classroom environment, campus environment) factors within the school environment (Allen et al., 2023; Sansom et al., 2023), we used Bronfenbrenner’s Social Ecological Model of Behavior Change as a framework to explore the academic help-seeking processes of undergraduate biology students. By using this model, we can better understand the complexities underlying student academic help-seeking behaviors, identify the factors that are most relevant to students in deciding to seek help, and provide instructors with a framework for developing academic help-seeking interventions.

RESEARCH DESIGN: We investigated the following research questions: (RQ1) Do students perceive that they need help understanding biology content; (RQ2) What individual characteristics predict help-seeking and avoidance behaviors?; and (RQ3) Which factors encourage students to seek academic help? We distributed a voluntary survey across six sections of four different biology courses (Anatomy & Physiology, Microbiology, Genetics, and Neuroscience; n=1,023) during two semesters at two R1 universities that used a modified version of the Computer Science Help-Seeking Scale (Parajes et al., 2004). Students were asked to indicate their perceived benefits of academic help-seeking and the likelihood that they would seek help, if needed. Additionally, students were asked to describe the factors that encourage student academic help-seeking. We addressed (RQ1) by determining the percentage of students who indicated that they needed help understanding course content. For (RQ2), we used mixed model analyses to determine the individual characteristics underlying the likelihood of seeking help and perceived benefits of help-seeking. To address (RQ3), we coded student responses to the questions “What, if anything, does your instructor do to ENCOURAGE you to ask questions in class or during office hours?” and “What, if anything, does your instructor do to DISCOURAGE you to ask questions in class or during office hours?” using open-ended thematic analysis.

ANALYSIS AND INTERPRETATION: (RQ1) Across all courses, ~51.2% of students perceived that they needed help to understand course content. (RQ2) However, we found that STEM majors were more likely to seek help (p<.01) and persons excluded because of their ethnicity or race (PEERs) were less likely to seek help (p< .01). Interestingly, these factors did not have an impact on the perceived benefits of help-seeking. Instead, we found that the perceived benefits of help-seeking were significantly impacted by course (p<.001). (RQ3) Students identified a variety of personal, social, and contextual factors that influenced their decisions to seek help from their instructors. Contextual factors included time, the physical learning environment, and course structure. Social factors included interactions with other students and the course instructor. Personal factors included student attitudes about learning and personal
characteristics (e.g., limited metacognition, shyness).

CONTRIBUTION: We investigated the academic help-seeking processes of students enrolled in undergraduate biology coursework and found that while most students perceive that they need help understanding content, STEM majors were more likely to seek help while PEERs avoid help-seeking. Furthermore, students identified a variety of contextual, social, and personal factors that influenced their decisions to seek help when needed. Taken together, these findings allow for understanding of the multiple factors that encourage student academic help-seeking in introductory biology courses and allows for the development of targeted interventions.

Understanding curricular influences on students’ science confidence and science identities during an introductory biology laboratory course.

Susan Hester (University of Arizona)*; Shane A Thomas (Washington State University); Sophia Holguin (University of Arizona); Jessica Lumm (University of Arizona); Molly S Bolger (University of Georgia)

Abstract:
Study Context
Students’ confidence for doing science (their science self-efficacy) and whether they identify as scientists may predict how likely they are to persist in STEM (e.g., Chemers et al., 2011; Estrada et al, 2018). These factors, in turn, can be impacted by classroom science experiences (e.g., Brownell et al., 2012; Jackson et al., 2023). An introductory lab course is often a student’s first encounter with “doing science.” Thus, intro lab courses may be uniquely important experiences for influencing students’ trajectories in science. We investigated how two introductory lab curricula impacted how students reflected on themselves as being like scientists and their reported gains in confidence: a “traditional,” content-based curriculum, and Authentic Inquiry through Modeling in Biology (AIM-Bio), which was intentionally designed to engage students in authentic cognitive and social aspects of science (Authors, 2018). We investigated how the courses impacted students’ confidence and what students saw as meaningful signals of being “like a scientist.” We based our approach on the premise that the development and impacts of an individual’s science identity are likely to be shaped by how they conceptualize science. We analyzed students’ own words, drawing on the idea that science identity is complex and shaped by individual factors (Carlone & Johnson, 2007).

Study
Two research questions guided the study. RQ1: How do students’ reasons for identifying as scientists evolve over the course of the two different introductory biology lab experiences? RQ2: In what areas did students gain confidence over the course of the two different introductory lab experiences? We collected data for this study in the Fall 2021 semester from consenting students in 11 sections each of the two different curricula (185 students in the traditional lab, 166 students in AIM-Bio). We collected and analyzed student responses to two open-ended reflection prompts given to students at different points in the semester. RQ1: As part of a longer pre-/post- reflection, we asked students to respond to the prompt, “Have you ever felt like a scientist? (yes/no) Please explain.” RQ2: At three points in the semester, students completed a reflection in which they responded to the prompt, “So far, have you gained confidence with anything in this lab course? If so, please explain.”

Analysis and Interpretations
We performed qualitative coding analysis of students’ responses to both prompts. We
developed both coding guides using an iterative grounded theory approach to identify recurrent themes present in the data (Charmaz, 2014). RQ1: We adapted and applied a previously-developed coding guide (Authors, 2018) describing students’ self-reported reasons for feeling like a scientist. RQ2: We developed and applied a coding scheme for identifying areas in which students described increased confidence in their reflection assignments.

Most students reported having felt like a scientist. Reasons given for feeling like a scientist, however, ranged from classroom-oriented—such as understanding science content—to being science practice-oriented—such as autonomy in designing their own experiments. We found that students often reported different reasons after the course, suggesting that the lab provided new signals of science identity. Patterns of pre/post change varied between curricula. The most-frequently gained codes for AIM-Bio were experimental design and experiencing autonomy; those for the traditional lab were formulating hypotheses, understanding content, and general lab comfort. Similarly, most students reported confidence gains in the lab, but we saw strikingly different patterns between curricula. Students in AIM-Bio were most likely to gain confidence in participating in science practices and laboratory skills, whereas students in the traditional lab were most likely to gain confidence in content understanding and academic performance.

Our results point to the variable impacts that intro lab experiences can have on how students frame meaningful participation in science and what it means to be a scientist, and their developing sense of themselves as competent scientists. In the AIM-Bio lab, students experienced authentic elements of science, and were more likely to build confidence in science practices and see participation in and ownership of science practices as meaningful signals of what it means to be a scientist.

Contribution

Our results bring additional evidence supporting model-based inquiry as a way to meaningfully engage large numbers of introductory students in science practices. Furthermore, previous studies investigating curricula impacts on students’ science identity and self-efficacy have typically relied on Likert surveys. By asking students to reflect in their own words, we have found variability in what drives students’ reports of feeling like scientists and what students experience as meaningful gains in confidence.

Session 2_D

Does a science-practice based laboratory curriculum impact students’ science self-efficacy, science identity and science community values? A randomized controlled study.

Shane A Thomas (Washington State University)*; Susan Hester (University of Arizona); Shavindi Ediriarachchi (University of Georgia); Molly S Bolger (University of Georgia)

Abstract:

STUDY CONTEXT: Undergraduate students’ perceptions about themselves, i.e., science self-efficacy, identity, and community values, are predictive of persistence into STEM careers, including for PEER (Persons Excluded due to Ethnicity or Race) groups (Estrada et al., 2018; Robinson et al., 2018). Studies have proposed that students’ experiences in science laboratory courses can have a strong impact on self-perceptions. In particular, curricula that allow students to directly participate science practices (e. g. hypothesizing, modeling) are associated
with more positive perceptions of oneself in science (Starr et al., 2020; Hanauer et al., 2017). However, it is difficult to directly test how science-practice based courses may impact students, because there is often a strong, self-selection effect. Students in groups with higher confidence and interest in science are more likely to take such courses. Furthermore, while science self-perceptions are known to be predictors of long-term STEM persistence, it is not fully understood what factors influence their development for undergraduates (Cole & Beck, 2022). We present a randomized controlled study to directly test how a science-practice based laboratory curriculum influenced students’ self-perceptions in a large introductory biology course. Our research took place at a Hispanic-Serving Institution, allowing us to contribute knowledge about the development of students’ science self-perceptions among PEER and non-PEER students.

STUDY DESIGN: Previously, we developed the Authentic Inquiry through Modeling in Biology (AIM-Bio) curriculum to infuse elements of research participation, in particular scientific modeling (authors, 2018; authors, 2021). Students generate diverse initial models to explain a biological phenomenon and then design and execute their own unique experiments to gather evidence and refine models. Our university adopted AIM-Bio to replace the Traditional laboratory curriculum. Over a 3-semester scale-up period, two curricula were taught and students were randomly assigned by self-selecting their lab section per usual, unaware of curricula differences (the instructional team assigned days of the week for each curriculum). To ensure fairness to students, the team matched course policies and student workload. We administered a previously-validated instrument to measure science self-efficacy, science identity, and science values at the start and end of the semester (Estrada et al., 2011). We asked the following research questions:

1) Do students in a science practice-based laboratory curriculum experience greater changes in self-perceptions compared to a traditional curriculum?
2) Are there interactions between laboratory curriculum, PEER status, gender, and/or first-generation status that may explain development of science self-efficacy, science identity, and/or science values?

Our study population included 1436 consenting students over three semesters (72% female, 49% White, 29% Hispanic/Latinx, 9% Asian, 6% Two or more races, 3% African American, 1% American Indian or Alaska Native, 4% no-ethnicity reported, and 26% first-generation status). Demographic data were obtained through university records. We examined incoming data to ensure a fair comparison between random groups using Chi-squared and t-tests. Only gender initially differed between groups (74% female in AIM-Bio and 69% female in Traditional).

ANALYSIS AND INTERPRETATION: We first used a linear mixed effect (LME) model (including demographic factors listed and curriculum as fixed effects) to address our research questions. We found that curriculum was a factor that influenced students’ science self-efficacy and science community values, but not science identity. We further tested these results using ANCOVA tests and found that science community values were significantly greater in the AIM-Bio curriculum, in comparison to the traditional curriculum, among the whole population and each demographic group tested (p<0.001). Additionally, our LME analysis revealed that an interaction effect between PEER status and curriculum influenced students’ science self-efficacy. We further tested this finding using ANCOVA tests and found that science self-efficacy was significantly greater in the AIM-Bio curriculum, in comparison to the traditional curriculum, among PEER students (p=0.005) and Hispanic students (p=0.027) but not non-PEER students (p=0.315).
CONTRIBUTION: Science self-perceptions predict STEM persistence, making it vital to understand how they develop, particularly among groups less likely to participate in STEM careers. We fill a gap in the literature using a randomized controlled study to illuminate the impact that science-practice based curriculum can have on how students come to view themselves in science. Our work adds to the literature supporting laboratory curricular reform efforts as a way to broaden legitimate science participation and positively influence student development.

Discussions of sexual diversity in nature increase student sense of belonging.

Paula E Adams (Auburn University)*; Ryan D.P. Dunk (Auburn University); Ash Zemenick (University of Michigan); Devan DeRamus (Auburn University); Zoe Diggs (Auburn University); Kate Kiani (Auburn University); Marjorie Weber (University of Michigan); Cissy Ballen (Auburn University)

Abstract:

STUDY CONTEXT: While biology coursework presents the opportunity to show the diversity of life on earth, biology courses often focus on narrow representations and depictions of what is ‘natural’ and observed in nature (Bickford, 2022). For sexual and gender minorities, who face considerable challenges in science and society, exclusionary narratives in undergraduate biology classrooms harm sense of belonging, career preparation, and interest in biology content (Atherton et al., 2016; Casper et al., 2022; Cooper & Brownell, 2016; Maloy et al., 2022; Miller et al., 2021; Sansone, 2019). The development and implementation of educational materials that are inclusive to all students and address gender essentialism directly are important but understudied (Hales, 2020; Zemenick et al., 2022). Zemenick et al. (2022) proposes a framework that prioritizes teaching the diversity of nature instead of overly simplistic representation of sexual systems as universally binary that may reinforce gender essentialism — the idea that gender is a biologically determined characteristic tied to sex. By emphasizing biodiversity, we can directly counteract assumptions that sex is universally binary in natural systems, and can include the social concept of gender within the biology classroom. Here we implement recommendations from Zemenick et al. (2022) and measure the impact on students.

RESEARCH DESIGN: We compare the impacts of a ‘diversity first’ gender-inclusive approach to teaching organismal biology to a traditional class section of the same course at a large university. Both sections use the same source material to develop their lectures, and largely cover the same content, but the ‘diversity first’ section included an additional lecture on sexual diversity in nature. The lecture followed the principles to embrace gender and sexual diversity laid out by Zemenick et al. (2022) and recreated slides about sexual reproduction from Project Biodiversify. One month following the ‘diversity first’ lecture, students in both sections of the course were asked to complete a survey including a combination of likert-scale, yes-no, and open-ended questions to assess the impact of the diversity first lecture on inclusion, sense of belonging, and experience in the course as well as what they learned about sex and gender in class.

ANALYSES AND INTERPRETATIONS: We ran generalized linear models to compare the results between classes and/or for students who self-identified as LGBTQ+. Students were asked if there were ways sex and gender were taught or discussed in the class that made them feel included (y/n). We found no significant difference between sections on inclusion (42.7% ‘yes,’ n=365). However, within the ‘diversity first’ section, students who self-identified as LGBTQ+ were significantly more likely to say they felt included by the way sex and gender
were discussed compared to students who did not identify as LGBTQ+ (78.9% ‘yes,’ p=0.0106; binary linear model). In the treatment section, students were asked about the impact of the ‘diversity first’ lecture on their experience in the course (1=very negative, 4=no impact, 7=very positive). Students reported an overall neutral impact on their experience (4.5 average); however, students who self-identified as LGBTQ+ reported a significantly positive impact (5.7 average, p=0.004). LGBTQ+ students also reported higher sense of belonging (5.15 average compared to 3.7 overall; p<0.001; 1=strongly disagree, 7=strongly agree) and felt more connected to the biology course content (5.2 average compared to 3.9 overall; p=0.0018). To measure understandings of the concepts of sex and gender, we asked students to define sex, gender, and the difference between them and thematically coded these responses to consensus. We found no difference in the way students defined sex, which they defined with biological concepts 87% of the time (eg: sexual characteristics, gametes, & chromosomes). However, we found that students incorrectly define gender using biological concepts of sex 44% (n=157) of the time in the traditional class section compared to 31% (n=139) in the gender-inclusive section. Additionally, 27% of students in the traditional class say that sex and gender are the same thing compared to 20% of students in the gender-inclusive course section.

CONTRIBUTION: This work shows that a gender-inclusive ‘diversity first’ approach to covering sex in introductory biology has a positive impact on LGBTQ+ students’ experience of the course, sense of belonging, and connection to course content. We also find that students in introductory biology courses conflate the definitions of sex and gender, but this can be improved with gender-inclusive instruction. This work should be of interest to SABER attendees as it shows that exposure to inclusive materials in introductory biology can have a positive impact on LGBTQ+ students and improve student understanding of the concepts of sex and gender.

Core Stages of Graduate Education Activate Imposter Syndrome for Biology Doctoral Students.

Ariel Steele (University of Minnesota)*; Grace-Divine L Boutouli (University of Minnesota); Lydia Swanson (University of Minnesota); Joshua Reid (Texas Tech University); A. Kelly Lane (University of Minnesota Twin Cities)

Abstract:
STUDY CONTEXT
Concerns for graduate student well-being are growing as graduate students report higher levels of stress, depression, and anxiety than the general population (Evans et al., 2018). While not a diagnosable mental illness, imposter phenomenon shares many characteristics with depression and anxiety (Cusak et al., 2013; McGregor et al., 2008) and is a persistent barrier for graduate students to fully engage with their programs (Sverdlik et al., 2020). Recent studies have explored how the graduate education environment contributes to imposter feelings (Chakraverty, 2019; Cohen & McConnell; Tao & Gloria, 2019), however, few studies have mapped imposter feelings to specific aspects of graduate education. In our study, we used a graduate student socialization framework (Weidman et al., 2020) to map biology doctoral students’ experiences with imposter phenomenon to specific aspects of graduate education to identify where and in what contexts imposter feelings are activated.

RESEARCH QUESTIONS
How do biology doctoral students describe their experiences with imposter phenomenon?
What aspects of graduate education activate imposter phenomenon for biology doctoral
students?

RESEARCH DESIGN
We conducted semi-structured interviews with 20 doctoral students in biology from two R1 institutions about their experiences with imposter phenomenon during graduate school. Participants were from a variety of backgrounds and identities. We used qualitative content analysis (Hsieh & Shannon, 2004) and thematic analysis to code interview transcripts and identify themes. We then mapped our codes and themes onto a timeline of graduate education, using a socialization framework to identify how salient experiences aligned with the stages of graduate education.

ANALYSES & INTERPRETATION
The first three authors analyzed the data through multiple rounds of coding. The first round began with coding one transcript together to develop a preliminary codebook. We then coded the remaining transcripts independently, meeting as a team to refine the codebook until we came to a consensus. In our analysis, we identified three themes: 1) the feelings and behaviors associated with imposter phenomenon, 2) the contexts that activated imposter phenomenon and 3) the sources of support participants sought to cope with imposter feelings.

The participants in this study associated imposter phenomenon with feelings of inadequacy, self-doubt, and fraudulence, which align with the characteristics identified in the literature. They also described the internal thoughts and feelings they associated with imposter phenomenon, including anxiety and depression, feelings of otherness, masking, and shame. Participants also described behaviors that included social isolation, working harder to overcorrect self-identified deficits, and procrastinating work that were related to their imposter feelings. For example, one participant explained that because of her imposter phenomenon, she isolated herself socially from her cohort just in case her program determined she was a fraud and should not be there.

Our analyses also noted that imposter phenomenon is context-dependent, with high-pressure, high-stakes situations being more likely to activate imposter feelings. Our timeline mapping found stages across graduate education can activate impostor feelings. Two timeframes of note were the stage before graduate education begins, where participants highlighted the strain of the application process and transition to graduate school, and the stage before candidacy due to the high-stakes qualifying exam process as context where their imposter feelings were activated.

Finally, participants described the sources of support they sought to cope with their imposter phenomenon, including therapy, friends and family, labmates, and trusted faculty mentors. Building a community of trusted individuals was important for alleviating imposter feelings for the participants, especially when negative support experiences reaffirmed imposter feelings for some of the participants and led them to avoid seeking support altogether. Overall, these findings provide insight into the contexts that activate impostor feelings for biology doctoral students, what feelings and behaviors are associated with imposter phenomenon as a result of those contexts, and how systems of support are important for alleviating impostor feelings.

CONTRIBUTION
Calls for graduate education reform focus on providing stronger support for graduate students across all stages of their development, including support for mental health and well-being (NASEM, 2018). By identifying when and in what context graduate students’ experiences with imposter phenomenon emerge, we can create support structures that minimize imposter feelings and help graduate students manage stress. With the findings of this study, we can
identify what aspects of graduate education need better support structures and develop testable interventions.

**The effect of exclusionary curriculum on LGBTQ+ students’ sense of belonging.**

Ryan D.P. Dunk (Auburn University)*; Dax Ovid (University of Georgia); Joshua Reid (Texas Tech University); Jeremiah Henning (University of South Alabama); Cissy Ballen (Auburn University)

Abstract:

Study Context:
Previous work on LGBTQ+ students in biology has shown they face unique challenges in classrooms implementing evidence-based practices (Cooper and Brownell 2017) and advocated for strategies that increase their comfort in the discipline (Cooper et al. 2020). Qualitative work by Casper et al. (2022) showed students are aware of narratives in biology curricula that promote gender essentialism (i.e., the belief that biological differences inherently lead to fixed, gendered behavioral differences) and binary thinking (male/female or man/woman to the exclusion of intersex and non-binary individuals). In light of this foundational work, we initiated a study to address the question: how do teaching materials about human reproduction impact sense of belonging for LGBTQ+ students in biology? To experimentally test this question, we collaborated with instructors from targeted institutions across the U.S. to present students with curricular materials that vary in the extent to which they present inclusive and accurate descriptions of sex and gender to determine their effect on feelings of belonging for LGBTQ+ students.

We ground this work in queer theory, a transdisciplinary field of study that seeks to expose and disrupt cisnormative and heteronormative assumptions by centering the lived reality of queer individuals. Specifically in the biological sciences, for example, queer theory challenges us to unearth and question the ways in which scientific knowledge about reproduction is presented in a way that normalizes heterosexual behavior such that other reproductive systems and behaviors are marginalized (Sumara and Davis 1999, Snyder and Broadway 2004, Gunckel 2009, Monk et al. 2019).

Study Design:

Our goal was to discover how the use of traditional, inaccurate, and non-inclusive (read: cis- and heteronormative) materials affect LGBTQ+ students’ sense of belonging. We gathered a large, nation-wide dataset and enacted a randomized, blinded experimental design. Institutional inclusion criteria included categorization as a Carnegie R1 or R2 school and a location in a state with active laws banning transgender healthcare to minors. In the fall of 2023, we deployed surveys to 10 classes at 7 institutions (N = 1528 respondents). To experimentally test our research question, we presented students with two excerpts of hypothetical introductory biology textbook materials and asked them a series of questions related to each excerpt. In the first excerpt, we presented all students with information about the role of RNA in transcription and translation; the second excerpt focused on reproduction in humans, and students randomly received one of two forms: one used language traditionally seen in such passages, including bio-essentialist and cis- and heteronormative language (hereafter the “traditional” treatment), and one eliminated such language for sake of accuracy (hereafter the “accurate” treatment). After the treatment stage, all students were prompted to fill out the 26-question Sense of Belonging Scale (SOBS; Hoffman et al. 2002) as well as demographic information, including a question where students answered if they considered themselves part of the LGBTQ+ community.
Analyses and Interpretations:
We used linear models with each of the four subscales of the SOBS as an outcome variable, with treatment (traditional vs. accurate) and LGBTQ+ community status (“yes”, “no”, “unsure”, “I am an ally”) as predictor variables. In addition to main effects from our predictor variables, we assessed the interaction between the two, as our focus was the effect of the traditional curriculum on LGBTQ+ students’ sense of belonging.
We observed a significant interaction effect between treatment and LGBTQ+ status for two subscales, Perceived Isolation and Perceived Peer Support. Specifically, LGBTQ+ students reported higher perceived isolation (interaction effect $p<0.001$) and lower perceived peer support (interaction effect $p<0.001$) as compared to both LGBTQ+ students who received the traditional materials and non-LGBTQ+ students. For the two other subscales (Perceived Classroom Comfort and Perceived Faculty Support), we found no significant effect of either treatment, LGBTQ+ status, or the interaction between the two.

Contributions:
Overall, these findings suggest the need for curricular reforms to enhance LGBTQ+ student sense of belonging. LGBTQ+ students had worse sense of belonging overall, experiencing higher isolation and lower peer support. When they were exposed to curricular materials that were cis- and heteronormative, the difference between LGBTQ+ students and their non-queer peers increased. This work should be of general interest to SABER attendees as it shows that even a brief exposure to non-inclusive materials at an introductory biology level can have a detrimental effect of LGBTQ+ student sense of belonging and presents evidence that should inspire us to challenge existing curricular materials.

Finding Your True North: A purpose-driven approach to developing students’ STEM career self-efficacy, identity and sense of belonging.

Shahnaz Masani (Michigan State University)*; Rhian Soloman (Michigan State University); Lauren Lambert (Michigan State University); Haiden Perkins (Arizona State University); Krysta Foster (Michigan State University)

Abstract:
For students in the sciences, there often seems to be only one pathway that combines their love of science and passion for helping people: medicine. But what if students approached their academic journey with a purpose-driven, as opposed to a destination-driven, mindset? Engaging in this type of exploration and reflection positively impacts students’ STEM self-efficacy and identity, helping to close opportunity gaps by promoting retention and reducing the time to graduation. However, this work remains siloed as ‘outside of class’ work, or in career-specific courses that are separate from students’ disciplinary courses, which allows students to see this work as important, but separate. In addition, this siloed approach means that only students who take these classes or engage with career services support individually have access to these opportunities. This opportunity gap is likely compounded for students from underrepresented and minoritized groups, creating a structural barrier where these students are expected to recognize the value and seek these opportunities in unfamiliar and often exclusionary environments. By integrating purpose-driven exploration and reflection into a student-centered biology classroom, we aim to engage students in purpose-driven planning, skill development and articulation within the context of their disciplinary learning experiences. Drawing on Social Cognitive Career Theory and Marcia’s Identity Formation Model we designed and assessed the IRL (In Real Life) lab curriculum, which was implemented in a student-centered introductory biology class across several semesters. Through the IRL lab, students engaged in activities that helped in (a) Identifying and articulating their purpose, which
we define as the intersection of their values, interests, skills, and the societal impact they prioritize in their work (b) Purpose-driven exploration and planning and (c) Making meaning of their in-class experiences within the context of their broader purpose and professional journey, and building professional networks. We evaluated the outcomes using a grounded theory based qualitative coding approach, triangulating data from class assignments, focus groups, and semi-structured interviews to assess the impacts of the IRL lab on students' STEM career identity formation and sense of belonging. We find that engaging with the IRL lab: (a) Increases students' career-related self-efficacy and outcome expectations, positively impacting their STEM career identity (b) Shifts their focus from a destination-driven approach (specific job or career) to a purpose-driven approach, thus impacting their identity formation process and (c) Increases access and students' sense of belonging by engaging them in making meaning of their disciplinary experiences and reflecting on how their academic goals align with their broader professional journey. STEM higher education is a choose your own adventure challenge where only some participants are equipped with the tools needed to navigate this new world. By engaging students in purpose-related exploration and reflection in a disciplinary, student-centered class, we break down this structural barrier by equipping tools and strategies they need to chart a path forward that aligns with their purpose, thus empowering ALL students to choose their own adventure.
Concurrent Short Talks - Session 3

Session3_A

The Mentoring Experiences in Research & Graduation Education (MERGE) survey: A robust tool for measuring graduate students’ negative mentoring experiences.

Trevor T Tuma (University of Georgia)*; John David Adams (University of Georgia); Jenny Choi (University of Georgia); Erin Dolan (University of Georgia)

Abstract:
Study Context: Effective, high-quality mentorship has been linked to many positive outcomes for students in STEM fields. Mentoring, like any relationship, can also include problematic or dysfunctional elements (Limeri et al., 2019; Tuma et al., 2021). Yet, there has been only modest research aimed at understanding the negative experiences doctoral students can have with their research mentors. This is concerning given the potential for these experiences to cause harm, particularly for students from marginalized and minoritized backgrounds. To date, there are no relevant measurement instruments that can be used to generate valid and reliable inferences about students’ negative mentoring experiences during their graduate education. To address this need, we aimed to develop and collect validity evidence for a new, theory-informed measure of graduate students negative mentoring experiences, which we have termed the Mentoring Experiences in Research and Graduate Education (MERGE).

Study Design: To guide the development of the MERGE, we adopted a construct validity framework to provide strong evidence of its utility for measuring graduate students’ negative mentoring experiences (AERA, et al., 2014; Messick, 1995). This process involved collecting and evaluating multiple forms of evidence with several national samples of doctoral students. We first drew from existing research on negative mentoring experiences in workplace (Eby et al., 2000) and undergraduate settings (Limeri et al., 2019) to conduct a qualitative study aimed at defining and delineating the content domain of the construct of negative mentoring (Tuma et al., 2021). We then drafted a pool of over 200 items based on the conceptual definitions and operational manifestations of doctoral students’ negative mentoring experiences (Tuma et al., 2021). In the present study, we sought to determine the extent to which the MERGE operates as a precise measure of students’ negative mentoring experiences during their graduate education.

Analyses & Interpretations: We first conducted cognitive interviews with 20 life science doctoral students to evaluate the clarity and comprehensibility of the items. We revised the items based on this feedback. We then collected feedback from ten experts in mentorship, career development, and measurement in the affective domain using a sorting task. We revised our items based on this feedback to minimize areas of construct irrelevance and underrepresentation to ensure that the item content aligned the theorized dimensions of the construct. Again, we iteratively revised the items and included measures of constructs predicted to be related and not related to establish the nomological network of variables related to negative mentoring experiences. We administered the items to a national sample of 565 life science doctoral students from 70 institutions across the United States and examined the internal structure of the scale and psychometric functioning of each item using factor analytic
and item response theory analyses. Through a series of confirmatory factor analyses, we also compared multiple competing measurement models using a variety of theoretically plausible higher order and nested models. Our factor analytic results provided greatest support for a ten-factor lower order model. Our predicted bivariate Pearson correlations were all in the hypothesized direction and provided evidence in strong support of the proposed nomological network. Finally, we also conducted measurement invariance analyses to examine the extent to which the scores from the MERGE functioned equivalently across various sociodemographic backgrounds. Our results provided evidence to suggest that the MERGE functions similarly across demographic groups.

Contribution: The main contribution of this work is the development of a psychometrically sound, multidimensional survey measure of graduate students' negative mentoring experiences. Our study provides strong validity evidence for the measures’ test content, response process, internal structure, and relationships to other variables. Scholars can use the MERGE to study the antecedents, correlates, and outcomes associated with negative mentoring experiences. Graduate programs and university leaders can also use the MERGE to assess the extent to which students are experiencing negative mentoring to inform program or university level improvements aimed at protecting students and supporting faculty in developing their mentoring competence. In sum, our study provides researchers and practitioners with a tool that can be used to identify negative mentoring experiences during graduate research training, determine their impacts, and inform efforts to mitigate or prevent these experiences.

Experiences of Christian and Muslim students during peer interactions in their undergraduate biology courses.

Baylee A Edwards (Arizona State University)*; Sara Brownell (Arizona State University)

Abstract:
STUDY CONTEXT: Increasingly, university courses have transitioned from traditional lecture to student-centered active learning, creating more opportunities for students to interact with each other in class and share details about themselves with one another (Freeman et al., 2014). Recent studies have indicated that these increased interactions in active learning can create situations where student identities are more salient, which could result in challenges for students with concealable stigmatized identities (CSIs) (Cooper et al., 2018; Cooper & Brownell, 2016). A student’s religious identity has been shown to be a CSI in the context of secular undergraduate biology classrooms in the United States (Barnes et al., 2021). However, it is unknown whether religious students experience challenges in their interactions with other students during class. Through two studies, we used the social psychology framework of concealable stigmatized identities to explore the experiences of Christian and Muslim students during peer interactions in undergraduate biology courses.

RESEARCH DESIGN: Specifically, we sought to understand (a) how salient Christian and Muslim students feel their religious identities are during peer interactions (b) their tendency to reveal their religious identity to their peers if it is concealable, (c) how beneficial they perceive it is to reveal to their peers, and (d) whether they anticipate and experience stigma when revealing during peer interactions. To do so, we conducted two interview studies. In our first study, we interviewed 30 Christian students from one institution in the southwestern United States, and in our second study, we interviewed 15 Muslim students from across the United States. In both studies, we asked students about their experiences during peer interactions in their undergraduate biology courses and whether their identity was concealable in biology.
ANALYSES AND INTERPRETATIONS: To analyze our interviews, we used a combination of inductive and deductive coding to create codebooks. Two researchers independently coded a subset of each set of interviews to establish interrater reliability and then coded the remaining interviews to agreement. We found similarities in the experiences of Christian and Muslim students during peer interactions in their undergraduate biology courses. Most Christian students and many Muslim students felt their religious identity was salient during peer interactions. Both Christian and Muslim students thought revealing their religious identity to their peers could be beneficial for multiple reasons, including combatting negative stereotypes about religious individuals in science and building connections with their peers. However, very few Christian or Muslim students with concealable identities actually revealed their religious identity to peers. Most Christian and Muslim students expressed that they anticipated stigma about their religious identities, including that they worried others might assume that they do not accept scientific ideas or are closed minded if they find out about their religious identity. However, very few Christian and Muslim students experienced stigma during peer interactions in their biology courses.

Despite these similarities, there were also interesting differences between the experiences of Christian and Muslim students. For example, many Christian students discussed that revealing their religious identity in class could help them find other religious students, which they felt would be beneficial; this may have been uniquely prevalent in our interviews with Christian students because there are a larger number of Christian students in undergraduate biology courses than Muslim students (Barnes et al., 2021). Alternatively, many Muslim students discussed the additional fear that their peers might view them as dangerous if they revealed their Muslim identity, and those concerns could come from the strong sentiments of Islamophobia that have been prevalent in the United States in recent decades (Sunar, 2017). Despite those concerns, many Muslims discussed that they anticipated less stigma in biology environments than in society broadly because their peers were more educated and less likely to judge them.

CONTRIBUTION: These results act as evidence that while religious students’ experiences can be similar in biology spaces, they differ as well, indicating that studies examining religion should disaggregate students by their denominations whenever possible. Finally, our findings highlight a need for future studies exploring the impact of learning environments in which students are given the opportunity to explicitly share their religious identities with one another, as those environments could reduce their anticipated stigma.

Why have peer mentors? Undergraduate STEM students’ perspectives on the nature and outcomes of traditional and peer mentors.

Krista Donis (Florida International University )*; Sarah L Eddy (University of Minnesota)

Abstract: 
Research Question or Problem: Mentoring plays an essential role in developing STEM students, because mentors provide them with opportunities for skill development, help them reach degree milestones and foster students’ affiliation to their discipline and future careers. Traditionally, STEM students receive mentorship from professors, researchers and faculty, that develop their disciplinary identities and grow their professional tool boxes. Despite the increasing value and use of traditional mentoring, one of the challenges has been identifying enough mentors to support the increasing number of students in higher education. Peer

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mentors offer an additional avenue of mentorship, by drawing on their own experiences as students to help other students as they navigate college. Peer mentors are embedded in courses, discipline-specific programs and research experiences. Traditional and peer mentors each have a distinct perspective and level of expertise; but we do not currently understand how students characterize these mentor figures, nor how these two mentoring types compare in terms of the support they provide. To characterize supports provided by peer and traditional mentors, we employed Nora and Crip’s (2007) model of mentoring that identifies four types of supports provided by mentors: (1) career support, where the mentor enhances the mentees’ advancement in an organization, their career exposure and visibility; (2) academic support, provided through tutoring and practical suggestions for improving academic performance; (3) psychosocial and emotional support, where the mentor enhances their mentees’ sense of competence and confidence; and (4) role modeling where the mentor provides opportunities for students to learn from them.

Research Design: The purpose of this study is to explore student’s perspectives on the nature (i.e. essential characteristics) of traditional and peer mentorship and student outcomes (i.e. types of mentoring support) that result from these relationships. We used a phenomenological approach to guide the design and analysis of this study, because we were interested in capturing the essence of traditional and peer mentorship through the lived experiences of students with mentors. We conducted semi-structured interviews with 14 undergraduate STEM students from two institutions (a Predominantly White Institution and a Hispanic Serving Institution). Students were asked to describe the mentor figures in their lives, share how each uniquely provided the 4 types of support suggested by Nora and Crisp (2007), as well as other supports they received that might not be covered by this model. Through thematic analysis of interviews, we identified repeated patterns of meaning in the data, and developed a codebook. The codebook included deductive codes that represent characteristics (nature) of each mentorship type; and inductive codes that align with Nora and Crisp’s (2007) four-support conceptualization (outcomes). We were also interested in the connections between the nature and outcomes of mentoring, so developed codes that reflected these associations.

Analyses and Interpretation: Our results reveal associations between the nature and outcomes that distinguish traditional and peer mentors. Traditional mentors, who have more professional experience, provide tailored career support by helping the student identify opportunities that will advance their career goals and provide accountability as they reach those goals. Since traditional mentors are multiple tiers above students, they act as role models that provide insight on the inner-workings of their careers and challenges they’ve faced along the way. As students see themselves reflected in their mentors, they gain a deeper understanding of their career choice and feel confident in their ability to succeed in the future. Peer Mentors are perceived as “equals” with similar academic and social experiences to students. Peer Mentors draw from their mutual experiences to provide immediate academic support to students, through tutoring and guidance on relevant courses to take. Students also felt they could be “academically” vulnerable with their peer mentor, sharing their struggles with the course content. Peer Mentors are also characterized by existing or developing friendships, which enables them to provide meaningful emotional support to students. Students suggest that peer mentors provide advice that goes beyond academics, such as being integrated in a new environment or coping with personal loss and isolation.

Contribution: This study advances our current understanding of traditional and peer mentors, by highlighting the characteristics and types of support they provide that make them an effective intervention in higher education. By shedding light on STEM students’ perceptions of mentoring, this work also has implications for the effective implementation and training of these mentor figures.
PEER students and faculty research mentors view benevolence differently in the relationship.

Star Lee (University of California, Irvine)*; Haley Miyasato (University of California, Irvine); Jocelyn Tirado (University of California, Irvine); Stephanie Dingwall (University of California, Riverside); Richard Cardullo (University of California, Riverside)

Abstract:
Research Question: Persons excluded because of their ethnicity or race (PEER) students who participate in undergraduate research experiences (URE) are more likely to graduate with a STEM degree, pursue graduate school, and have STEM careers compared to students without URE (Estrada et al., 2011; Jones et al., 2010; Schultz et al., 2011). Students' benefits from UREs are dependent on how they are mentored, and a major factor is whether students interact directly with faculty research mentors (Aikens et al., 2016). PEER students who trust their faculty research mentors are more motivated and have higher career expectations (Ream et al., 2014). Benevolence is critical to building trust (Mayer et al., 1995), and there is little known about how trust develops between PEER students and their faculty research mentors. To better understand the role of benevolence in this relationship, we investigated how actions by mentors are interpreted as acts of caring by PEER students and faculty mentors themselves.

Research Design: The California Louis Stokes Alliance for Minority Participation (CAMP) program aims to support and increase the number of PEER STEM graduate students and professionals. An active program at all nine undergraduate University of California (UC) campuses, CAMP students are involved in faculty-mentored research. To learn more about the faculty mentor's benevolence, CAMP students (n = 11) and faculty mentors (n = 10) were interviewed and participants were asked questions about the faculty mentor's benevolence. For example, students were asked “Does your faculty research mentor care about how you feel? How do you know or how do they show you?”. Faculty were asked similar questions like “Do you care about how your student feels? How do they know you do or how do you show them?”. Interviews were on zoom and audiorecorded. Recordings were transcribed and transcriptions were analyzed.

Analyses and Interpretations: Based on a process-oriented model of mentorship (Eby et al., 2013), we used deductive coding to differentiate between two major themes: instrumental support and psychosocial support of mentors. Instrumental support codes focused on concrete ways faculty mentors supported students' research and career aspirations. Psychosocial support codes focused on methods used by faculty to support their students' socioemotional health. Students and faculty mentors emphasized different types of support as acts of caring by mentors. Most students focused on their mentor's instrumental support by providing resources and collaborating on research. Most faculty described providing psychosocial support to their students by building community and creating rapport. A couple of students and faculty explained how barriers prevented them from building a more personal relationship.

Contribution: This study suggests there is a difference in how faculty mentors and PEER students give and receive care in mentor-mentee relationships in research. Findings from this study indicate how faculty mentors may better support our PEER students in URE.
The impact of research, teaching, mentoring, and service on science faculty depression.

Katelyn M Cooper (Arizona State University); Tasneem F Mohammed (ASU); Sara E Brownell (Arizona State University)

Abstract:
Study context: A recent study of over 2000 US science faculty found that a quarter (24.7%) identify as having depression (Authors, under review). The demands associated with academia have been found to cause occupational stress and burnout among faculty, but these expectations have not been explored as they relate to symptoms of depression among science faculty specifically. Further, it is unknown how symptoms of depression affect faculty members' abilities to carry out these academic expectations. Drawing from behavioral theories of depression (Lewinsohn, 1974; Martell et al., 2001; Carvalho et al., 2011), we hypothesized that lack of reward, lack of positive reinforcement, and encouragement of passive behaviors in the context of teaching, mentoring, research, and service lead to the exacerbation of depressive symptoms among faculty. We also hypothesized that depression would impact faculty cognitive domains (Grabinger et al., 2018), creating challenges when they go to carry out academic responsibilities.

Study design and analyses: We conducted a qualitative interview study of 40 faculty with depression across biology, chemistry, geosciences, and physics departments at research-intensive institutions to answer our research questions: 1) What aspects of teaching, mentoring, research, and service exacerbate and alleviate symptoms of depression among science faculty? 2) How do symptoms of depression negatively or positively impact faculty experiences engaging in teaching, mentoring, research, and service?

We recruited participants by reaching out to faculty at research-intensive institutions in the U.S. who identified as having depression on a national survey. We limited this first study to research-intensive institutions to standardize the expectations of teaching, research, mentoring and service. 40 faculty agreed to participate in the interview study. All interviews were conducted by a faculty member who identified as having depression. We used inductive coding to identify themes to answer our research questions and coded the interviews after establishing interrater reliability.

Interpretation: Our study revealed that teaching can exacerbate faculty depression when they receive negative reinforcement from students (e.g., rude emails, poor evaluations) and when demands become overwhelming. Most faculty described “masking” or hiding their symptoms of depression during teaching, which could worsen their depression. However, watching students improve, having a passion for teaching, and the structure of teaching helped alleviate depressive symptoms. A lack of mentee progress, mentee demands, and mentee conflict could exacerbate symptoms of depression for mentoring, while positive interactions and reinforcement were found to lessen depressive symptoms. If faculty perceived that the service that they engaged in was meaningless or that the content of the service was depressing (e.g., reviewing academic integrity violations or unsuccessful PhD applications), it could worsen their depression while meaningful service was positive. Finally, faculty highlighted that having a passion for research and receiving positive reinforcement (e.g., grants or papers accepted, awards) can alleviate depressive symptoms. However, faculty reported that if they do not meet their own expectations or the expectations of others when it comes to research, it exacerbates their depression, as does a lack of recognition for their work, perceiving their research is meaningless, and being unfairly critiqued. Faculty highlighted that the time that research takes, and the lack of structure can also be difficult for their depression. When talking about how
depression affects their abilities to carry out academic responsibilities, faculty highlighted that it made them more irritable and less patient both when teaching and when mentoring students. However, they also highlighted that depression made them a more compassionate and understanding person in both circumstances. With regard to service, faculty described that depression can make them irritable and argumentative when trying to collaborate on service efforts and can also cause them to question their own judgements. Finally, many faculty highlighted that their depression made it difficult to be creative and generative in research, which often affected the process of writing. They also cited that it caused them to be overly self-critical and lessened their research productivity.

Contribution: Given that 25% of science faculty identify as having depression, it is imperative that we understand how academia impacts faculty mental health. This is the first study to illuminate the ways in which teaching, mentoring, research, and service affect faculty depression and how depression in turn impacts science faculty experiences carrying out their academic responsibilities.

Session 3_B

Math Meets Biology: Analyzing Undergraduate Biology Students’ Sensemaking in Hardy-Weinberg Equilibrium and Inheritance Written Problems.

Amber G Armstrong (University of Minnesota)*; Desi (University of Minnesota); Michael Fleming (CSU Stanislaus); Kevin Haudek (Michigan State University); Anita Schuchardt (University of Minnesota)

Abstract:
STUDY CONTEXT & THEORETICAL FRAMEWORK
Many concepts in biology rely on mathematical principles, including Hardy-Weinberg Equilibrium (HWE) and inheritance. When students encounter a mathematical representation in biology, they can use a variety of resources from biology and mathematics to process its meaning (Hammer, 2000). This process of making meaning of new situations using knowledge acquired from past experiences is defined as sensemaking (Martin & Kasmer, 2009). Students often struggle to make sense of connections between biological concepts and mathematical representations, adversely affecting problem solving (Eichenlaub & Redish, 2018). To better understand how students make sense of the mathematics in science, the Sci-Math Sensemaking Framework (Authors, 2021a) has been developed and used to characterize 4 types of science sensemaking and 5 types of mathematics sensemaking during student discussions and interviews (Authors, accepted; Kaldaras & Wieman, 2023). Few studies have examined types of sensemaking elicited by written prompts, which can allow for broader use of formative assessment of students’ mathematics and science sensemaking.

RQ: How do students engage in science and mathematics sensemaking in written responses to different prompts when solving HWE and inheritance problems?

STUDY DESIGN
Two items (one each for HWE and inheritance), each consisting of multiple sub prompts, were designed to elicit science and mathematics sensemaking in students’ written answers. The items were randomly distributed to 78 undergraduates at the end of an introductory biology course (40 HWE, 38 inheritance). Twenty student responses for each item were randomly selected for initial analysis.
ANALYSES & INTERPRETATION
Two authors independently coded written responses using the Sci-Math Sensemaking Framework for types of sensemaking students elicited for each sub prompt (Agreement: 92% inheritance; 93% HWE). Disagreements were resolved by discussion. Across sub prompts, responses showed multiple types of both science and mathematics sensemaking with differences between sub prompts and question contexts. In many responses, students used more than one type of sensemaking (Table 1).

Table 1
Percent of responses for selected sub prompts with 1 & 2 or more (2+) types of sensemaking
HWE A: Sci 0, Ma 45, 2+Sci 0, 2+Ma 0, 2+SciMa 30
HWE C: Sci 15, Ma 0, 2+Sci 45, 2+Ma 0, 2+SciMa 30
Inher A: Sci 0, Ma 25, 2+Sci 0, 2+Ma 0, 2+SciMa 60
Inher G: Sci 0, Ma 50, 2+Sci 0, 2+Ma 0, 2+SciMa 30
Inher H: Sci 0, Ma 20, 2+Sci 0, 2+Ma 10, 2+SciMa 50

Many responses to HWE involved 2 or more science sensemaking types. Students tended to use Sci-Pattern sensemaking (trends among scientific phenomena) and Sci-Mechanism sensemaking (biological mechanisms). Given a prompt about why self-crossing can lead to increased recessive homozygote frequency over time (HWE C), one student wrote, “There is less genetic diversity (SP) and when a new allele is introduced for the first cross-breeding of the plant, that trait gets bred again in the next generation (SM) and will become more prevalent after generations (SP).” The student connected self-crossing across generations to the extent of genetic diversity (Sci-Pattern, SP), followed by a counterexample of a mechanism by which diversity might be introduced (cross-breeding, Sci-Mechanism, SM).

Responses to inheritance sub prompts showed multiple types of mathematics sensemaking and combinations of mathematics and science sensemaking (Table 1). One sub prompt (A) asked why the formula \( P(G) \cdot P(h) = P(Gh) \) can be used to determine the probability that a female with the genotype GgHh will produce eggs containing “G” and “h” alleles. A student responded, “We multiply the two probabilities because we are looking to see the probability of them occurring together, not at two separate times (MR). This equation relates to the biological process of meiosis (SM) as we are looking at the probability of a gamete that is produced based on alleles present in the parents. As meiosis has a lot of processes that occur within it to randomize the end alleles of the gamete (SM), this allows for the simplification of mathematical formula-allele probability multiplied by allele probability (MS).” The student justified the use of multiplication by connecting to the mathematical rule of probability of 2 events occurring together (Math-Rule, MR). They also explained that the mechanism of meiosis (Sci-Mechanism) is represented by the form of the equation, engaging in another Math sensemaking (Math-Structure, MS).

CONTRIBUTION
This study demonstrated that even within the same biological context, students displayed different types of sensemaking in their written responses to different sub prompts. The possible affordances and constraints of different prompt wording on eliciting sensemaking will be discussed. We are exploring how students are using mathematics and science sensemaking in these written responses.
Interpreting Student Systematic Reasoning Processes with Pedigree Analysis.

Christian M Cammarota (Rochester Institute of Technology)*; Ben Zwickl (Rochester Institute of Technology); Dina Newman (Rochester Institute of Technology)

Abstract:
Study Context: Quantitative reasoning skills are essential tools for complex problem solving in STEM. The need for these skills in the life sciences has been highlighted by various national reports such as BIO2010 (NRC 2003), Vision and Change (AAAS 2011), Next Generation Science Standards (2013), and the Bioskills Guide (Clemmons et al 2020). Several assessments have been designed to gauge student performance in this area such as the Biological Science Quantitative Reasoning Exam (Stranhope et al 2017), the Quantitative Modelling Biology Undergraduate Assessment (Mayes et al 2019), the BioCalculus Assessment (Taylor et al 2020), and the Inference-Making and Reasoning in Biology Assessment (Cromley et al 2021). Though these tools provide useful feedback to aid instruction, more context is needed to determine interventions that could help improve quantitative reasoning. Previous studies have begun to address this need by analyzing student work with student generated problem-solving processes (Prevost and Lemons 2016, Averna et al 2021).

Study Design: Our work addresses the need for contextualization of student reasoning by direct observation of students solving genetics logic problems. We build upon prior work (e.g. Smith 1988) by conducting think-aloud interviews with 15 biology undergraduate students who have taken a genetics course. Students analyze multiple pedigrees for these interviews; they are asked to make inferences about inheritance patterns of genetic traits and to identify pedigrees that are consistent with a particular inheritance pattern, both verbally and using a recorded drawing tablet. We begin the analysis by applying Polya’s problem solving framework–Understanding the Problem, Devising a Plan, Carrying out the Plan, and Looking Back–to student interviews, with ties to Domain Specific Problem Solving, especially in Genetics (Polya 1945, Averna et al 2021). We look for both the presence of misconceptions in standard pedigree analysis as well as inconsistencies in logical solution (Grimes et al 2022). We then sort the misconceptions and inconsistencies into a timeline for problem solving. Additionally, we use the student-written artifacts to provide additional context to verbal answers. The artifacts allow us to analyze created representations and annotations students use to supplement their thought patterns (Meltzer 2005). The artifacts allow us to identify at what point in the problem-solving process representational aids are used to support student reasoning.

Analyses and Interpretations: Think aloud interviews provide us with examples of students solving problems in real time and allow us to identify inconsistencies with student logic. We find that students who fail to devise a plan cannot look back through their work to see if their solution fits the problem as well as students with well-developed plans. Additionally, students who fail to use these metacognitive practices often misapply representations such as Punnett Squares to test for possible modes of inheritance. Punnett Squares and written genotypes are used out of habit rather than for utility in such cases. Regardless of metacognitive practice, we find that cognitive load is particularly difficult for students solving problems with pedigrees but can be lessened slightly by student generated representations.

Contribution: This qualitative research project contributes to an extensive field studying student understanding in genetics and problem solving (Smith 1988, Averna et al 2021, Timm et al 2022, 2023). Our work extends previous studies by observing students directly during the
problem-solving process, including observation of failed and adjusted strategies. The written artifacts that students generate provide context for how students are implementing problem solving strategies. Our analysis shows that without a well-defined plan, representational and annotated aids can have little value to solving problems. We suggest that teaching problem solving through a metacognitive approach can serve to not only help students focus their time, but also facilitates better use of representational tools.

**Principles Guide Successful Mechanistic Reasoning in Biology.**

Kylie Todd (Michigan State University); Jess Cherniawsky (Michigan State University); Aeryn VanDerSlik (Michigan State University); Eli Cole (Michigan State University); Jennifer H Doherty (Michigan State University)*

Abstract:
Research Question. Mechanistic reasoning is a powerful strategy used to organize one’s thinking (Krist et al., 2019) by leveraging the properties and behaviors of underlying entities to explain how and why phenomena occur (Krist et al., 2019; Russ et al., 2008). Modell identified seven “general models” (i.e., principles, core concepts) in organismal biology that could serve as a cognitive framework for students to use to reason mechanistically about a variety of seemingly-distinct processes. Though there are frameworks to analyze students’ use of mechanistic reasoning, there is currently no framework to analyze how biology students use principles or core concepts to support their use of mechanistic reasoning to solve complex problems. Research aim 1: Develop a framework to describe students’ use of the flow down gradients principle in their mechanistic reasoning. Research aim 2: Determine if students that use flow down gradients to guide their reasoning are more likely to construct correct explanations to novel biological problems.

Research Design. We recorded and transcribed weekly in-class discussions of 16 introductory biology students across 4 small groups across a term as they worked to solve complex problems related to the principle of flow down gradients (rate of movement = gradient/resistance) (n=42 discussions). We analyzed these discussions with the assumption that students’ knowledge is dynamically constructed during problem solving. Aim 1: Through a process of iterative coding, covening, and adjusting, we developed a flow down gradients mechanistic reasoning framework. We developed this framework by combining established frameworks for mechanistic reasoning (Russ et al, 2009; Krist et al, 2019) and flow down gradients reasoning (Scott et al., 2020, Doherty et al. 2023) with emergent patterns from our data. Aim 2: Using this framework, we categorized discussions as either students using flow down gradients to guide their reasoning or not using flow down gradients to guide their reasoning. Additionally, we created a rubric to determine if discussions generated correct, partially correct, or incorrect explanations to the complex problems. No completely incorrect explanations were found. Therefore, we conducted a chi square analysis with these categories to determine if students that used flow down gradients to guide their problem solving were more likely to generate correct rather than partially correct explanations.

Analyses. Aim 1: Our flow down gradients mechanistic reasoning framework has two parts: mechanistic reasoning codes and flow down gradients reasoning criteria. The flow down gradients mechanistic reasoning codes describe students’ problem solving by identifying 1) mechanistic reasoning without flow down gradients, 2) mechanistic reasoning using the components of the flow down gradients relationship individually (e.g., gradient OR resistance), and 3) mechanistic reasoning integrating all the components of the flow down gradients relationship (rate of movement = gradient/resistance). The flow down gradients criteria
categorize discussions as students having used flow down gradients to guide their reasoning or not having used flow down gradients to guide their reasoning. A discussion in which students use flow down gradients to guide their reasoning must identify a flow, continuously reason with the components of the flow down gradients relationship, and reason with the integrated flow down gradients relationship at least once. Aim 2: We found that students who used flow down gradients to guide their reasoning were more likely to construct correct explanations for novel biological problems. Sixty-nine percent of discussions in which students used flow down gradients to guide their reasoning constructed correct explanations, whereas only thirty-eight percent of discussions in which students did not use flow down gradients constructed correct explanations \( (p = 0.03) \).

Contribution. We provide empirical evidence to support Modell’s assertion that teaching students to use principles (or core concepts) to guide their reasoning supports students’ ability to construct correct mechanistic explanations. Our flow down gradient mechanistic reasoning framework advances our current understanding of how students use principles to guide their mechanistic reasoning when solving complex biological problems. The framework can also be used by instructors and researchers to measure the impact of interventions designed to increase the use of principle-based mechanistic reasoning.

**Graphing Under the Microscope: Examining Undergraduates’ Graph Knowledge in Introductory Biology Courses.**

Nouran E Amin (Purdue University)*; Kal Holder (Purdue University); Eli Meir (SimBio); Susan Maruca (SimBio); Joel Abraham (CSU Fullerton); Stephanie M Gardner (Purdue University)

**Abstract:**
Study Context: Graphs serve as vital tools for visualizing and interpreting biological data, requiring students to integrate quantitative knowledge, familiarity with graph types, and attention to visuospatial aspects (Roth & Lee, 2004; Shah & Hoeffner, 2002; Tufte, 2001). The selection of an appropriate graph type hinges on students’ cognitive understanding of the underlying data, emphasizing the importance of effective graphing practices. Despite limited exploration in undergraduate settings, studies underscore the challenges undergraduate biology students face in constructing and interpreting graphs (Angra & Gardner, 2017; Berge & Boote, 2017; Harsh & Schmitt-Harsh, 2016). Our current study is an extension of our earlier work which explored the reasoning patterns of introductory biology students when constructing their own graphs versus evaluating pre-made graphs using a performance-based assessment tool. The previous findings illuminated disparities between the graphs students crafted and those they selected from pre-made graph sets. Furthermore, students reasoned around data analysis and statistics concepts when justifying their selections from a set of pre-made graphs as opposed to their explanations when constructing their own graphs. However, these analyses were based on students’ written open-ended responses to the assessment \( (N=301) \) which did not allow us to explore the sources of the variation and the features of students’ knowledge in order to have a deeper understanding and identify targets for instruction. The Conceptual Dynamics (CD) framework offers a lens through which the stability of students’ knowledge can be revealed (Scherr, 2007). Further, the CD framework gave rise to the Dynamic Mental Construct (DMC) (Sherin, 2007) which acknowledges that student knowledge and reasoning is not always stable, and that context can influence how students activate nodes (concepts or pieces of knowledge) and how these nodes become modes (or connections made between two or more concepts). Therefore, we conducted think-aloud interviews to examine the dynamic nature and potential context dependence of students’ graphing knowledge to
better understand the differences between what students apply in the two tasks (constructing versus evaluating graphs).

Study Design: We aimed to answer the research question: Why does the application of graph knowledge vary when constructing versus evaluating graphs? We recruited students from diverse institutions. Our current sample consists of 8 introductory biology students (7 women, 2 men) from 4-year universities (4R1, 2R2, 1R3, 1-Masters granting institution) for a 1-hour virtual think-aloud interview. The first part of the interview consists of students completing the graphing assessment in which they were provided with background information on a biological scenario along with a hypothesis, three predictions, and a dataset in which they are asked to complete a series of tasks to evaluate the predictions. In addition to creating their own graphs, within the assessment students are asked to pick a “best graph” from a set of six pre-made graphs and provide their reasoning. Upon completing the assessment, the participants were then asked a series of follow-up questions on their choices for graphs they made and selected to reveal their application of graph knowledge.

Analyses and Interpretations: Utilizing our existing codebooks along with features of the Conceptual Dynamics (CD) Framework and the Dynamic Mental Construct (DMC), we have coded each student's interview transcript characterizing the stability and variability of their graph knowledge. Four authors read and coded all interview transcripts, meeting regularly to discuss any differences in coding and reach a consensus for inter-rater reliability. The present analyses indicate that students who opted to select pre-made graph types they did not construct themselves displayed “mode-switching” or made connections between different nodes or graph knowledge concepts not previously activated when they were constructing their graphs. Conversely, students who reasoned around similar graphs to the ones they constructed displayed “mode-stability” or the application of a comparable set of knowledge.

Contribution: The findings from this study further our research interests and add to the literature a dynamic and context-dependent view of student knowledge within the setting of graphing biological data. The analytic approach using the CD and DMC framework not only allows us to describe students’ graph knowledge but can point instructors to specific instructional foci to better foster quantitative competence among undergraduate biology students, aligning with national calls for graduates equipped to tackle 21st-century challenges (AAAS, 2011; NRC, 2009).

Model Provision Versus Model Creation: Impacts on Student Reasoning about Ecosystem Carbon Cycling.

Seth W Hunt (Michigan State University)*; Tammy M Long (Michigan State University)

Abstract:
Study Context: Biology is the study of living systems. Being able to reason about systems is a necessary outcome for undergraduate biology students, particularly if they are to tackle the complex problems facing our world today. Modeling systems is a foundational scientific practice. Assessments that ask students to reason with and create models can reveal their ability to think about biological systems and contribute to their development of systems thinking skills (Lee and Jones 2018; Wilson et al 2020).

Understanding how carbon cycles between autotrophs and heterotrophs in ecosystems is a core ecological concept (ESA 4DEE framework) taught in many introductory biology classrooms. Modeling the ecosystem processes involved in carbon cycling can be beneficial to
students’ understandings of more complex biological phenomena, such as global climate change. Being able to predict the consequences of perturbations to such cycling would represent both an important systems thinking skill (Momsen et al 2022) as well as cross-cutting concept (NRC 2012).

Our study examines the effect that model provision versus model creation has on the elicitation of systems thinking skills within a carbon cycling context in undergraduate introductory biology students.

Research Design: Students (n=283) were provided background information about carbon cycling between algae and bacteria in a river ecosystem and randomly placed into one of two treatment groups. The Model Provided (MP) group was provided a model describing the system while the Model Constructing (MC) group was asked to create one.

Both groups answered two types of questions that were informed by the Biology Systems Thinking (BST) framework (Momsen et al 2022): (1) Interpretive questions asked students with identifying systems specifics like the relevant structures and behaviors and the overall function and aligned with Level 1 of the BST, and (2) Predictive questions that tasked students to forecast how individual structures would change and the overall function and aligned with Levels 2 and 3 of the BST. Further information regarding the differential effect that increasing temperature has on photosynthesis versus respiration followed. Students were told the temperature has increased and asked a second set of questions. They were also asked to explain their reasoning in answering these questions.

We applied a grounded coding rubric to analyze student responses. Interpretative questions were coded for correctly identifying system components and relationships, such as the form and process by which carbon was taken in or released by algae and bacteria. Predictive questions were additionally coded for direct and indirect ecological effects, aspects of mechanistic reasoning, and expansion beyond the stated system boundaries.

Analyses and Interpretation: We used both binary logistic and poisson regression to analyze treatment effects.

For the interpretative questions, students in the MP treatment included significantly more structures and behaviors in their responses than the MC treatment. The MP treatment was also significantly more likely to correctly identify carbon flow into and out of algae via photosynthesis, but there were differences with algal respiration. The MP treatment was also more likely to fully describe carbon flow into and out of bacteria.

For predictive questions, the MP treatment described indirect, ecological effects more when tasked with explaining predicted effects after either bacteria or algae increased in population size. The MC group was more likely to discuss changes to carbon generally (such as when discussing the system function) for the same questions. The MC group was also more likely to describe changes to algal metabolism when asked to predict what happens when the algae either increase or decrease.

In conclusion, model provision appears to confer benefit for questions that involve describing the system and require Level 1 systems thinking skills. Model creation begins to add benefit when students are asked to use the system to solve problems which require Levels 2 or 3 systems thinking skills.
Contribution: Nutrient cycling is a foundational concept underlying many problematic ecological issues including climate change. Understanding how biology students incorporate systems thinking skills to explore, navigate and explain nutrient cycling models is an important step toward preparing students for reasoning about complex systems. This understanding can lead to better instructional methods with the ultimate goal of producing a more environmentally literate society that is more informed and capable of answering complex ecological problems.

Session 3_C

A Power of Place Learning Experience and Research Network (APPLE R Net) to Support Community College Scientific Civic Engagement.

Deidre Jaeger (University of Colorado Boulder)*; Amy K. Dunbar-Wallis (University of Colorado, Boulder); Teresa Bilinski (University of Colorado Boulder); Maggie Prater (Front Range Community College); Laura K Baumgartner (Front Range Community College); Paige Littman (University of Colorado Boulder); Paul Le (University of Colorado Denver); Sriparna Saha (CU Boulder); Molly Callaway (University of Colorado Boulder); Lisa A Corwin (University of Colorado Boulder)

Abstract:
STUDY CONTEXT: Place-based research experiences may be especially impactful when implemented in Community College (CC) Biology classes as CC students often reside near their institution and are more likely to reside and work locally post-graduation, employing their skills to help local communities (Baker 1994; Robinson 2020). Civic engagement improves skills needed for leadership and social change, contributes to cohesion between cultural and ethnic groups, and increases appreciation for diversity (Astin & Sax, 1998; Birdwell et al., 2013; Pascarella & Terensini 2005). While there is significant evidence that Course-based Undergraduate Research Experiences (CUREs) promote advantageous student outcomes (Corwin et al. 2015; Dolan et al. 2016; Rodenbusch et al. 2016), we lack data on how participation in locally-relevant community-engaged CUREs impact student’s perception of how they can help their community. To address this gap, we assess changes in four important predictors of students’ future science civic engagement over the course of a place-based CURE: a) knowing how to help their community (civic knowledge), planning to help their community in the future (civic action), feeling like their actions will make a positive impact (civic efficacy), and valuing the opportunity to help their community (civic value). We hypothesize that implementing short, modular Power of Place CURE (PoP-CURE) curricula at local community-serving institutions of higher education (i.e., CCs) will increase students’ likelihood to participate in civic engagement using their science skills.

RESEARCH DESIGN: 378 students participated in the “Apple Tree Project” PoP-CUREs in 2022 and 2023. Students attended four community colleges and three minority-serving four-year colleges. All students had one day in the field, and participated in classroom content for variable amounts of time ranging between 1-8 weeks depending on instructor choice. We used a mixed-methods approach and collected quantitative pre and post survey data and qualitative interview data. We used the Predictors of Scientific Civic Engagement (PSCE) Scale to assess changes in students’ likelihood to use their science skills for civic engagement (Alam et al. 2022). We also asked students about their intent to persist in the sciences (Estrada et al. 2016). To better understand potential mechanisms of change, we did thematic analysis based on interview and focus group responses and designated a priori codes according to (Onwuegbuzie & Combs 2010) to allow for data triangulation.
ANALYSIS AND INTERPRETATION:
We will use mixed model analysis to understand how student outcomes (N=122) change after the curricula intervention and how semester, institution type (2 or 4 year), and ethnicity impacted their survey responses regarding civic knowledge, action, efficacy and value. Students and institutions will be controlled for using random effects. Preliminary analyses using Wilcoxon Rank-Sum tests are promising. Students in the Spring 2023 semester completing both surveys (N = 81) reported significantly higher science civic knowledge related to the community in which their institution was located. On average, students shifted from “somewhat disagree” to “somewhat agree” after completing the APPLE R Net field module on the PSCE 6-point scale (1 = Completely agree and 6 = Completely disagree; pre: 3.9, post 4.4, st error 0.1; Z =2118, p= 0.003). We found students reported a significantly higher likelihood to take science civic action in the Spring 2023 semester (pre: 3.3, st. error 0.1, post: 3.7, st error 0.1; Z =2362, p= 0.03). Preliminary analysis of the interview and focus data indicate students felt more likely to know how to help their community in the context of the apple tree subject matter after taking the class, but the time and resources needed to take immediate action in an impactful way were less available in their current status as a student. In some cases, however, some students expressed a desire and intent to continue to connect with public-facing field sites beyond the class.

CONTRIBUTION: Our findings contribute to an understanding of how short place-based CUREs function in biology education to promote students’ likelihood of using science skills to help their community. Our preliminary results suggest that these PoP-CUREs are not likely to shift how important students think it is to help their community, however they are effective to equip students with practical knowledge of how they might use their science skills and inspire some motivation to take action in helping their community. We saw increases in scientific civic knowledge at both two- and four- year institutions, suggesting PoP-CUREs can be important early in a student’s science career to develop skills in civic engagement. These course-based experiences are planting seeds for what students could do to help their future communities.

A proof of concept for Hopelessness Theory of Depression: Attributions help explain why challenges in research can exacerbate depressive symptoms among science undergraduates and graduates.

Tasneem F Mohammed (ASU)*; Mary A Kahraman (Arizona State University); Celestial J Pigart-Coleman (Arizona State University); Katelyn M Cooper (Arizona State University)

Abstract:
Study Context: Depression is estimated to affect 40% of undergraduate and graduate students in the sciences (Agyapong-Opoku et al., 2023, Evans et al., 2018) and aspects of scientific research experiences can alleviate and exacerbate students’ depressive symptoms (Cooper et al., 2020). Specifically, experiencing failure, negative reinforcement, a lack of guidance, and isolation can be deleterious for students’ mental health while success, positive reinforcement, guidance, and belonging can lessen depressive symptoms. However, the mechanisms explaining why these relationships exist has not been described. For example, how does encountering a challenge in research lead to worsening mental health? The Hopelessness Theory of Depression (Abramson et al., 1989) describes a mechanism by which individuals become hopeless and develop symptoms of depression. It suggests that when an individual experiences a negative life event, if they make internal, stable, or global attributions for the event, it can lead them to feel hopeless and exacerbate their depression (Abramson et al., 1978). Internal attributions are when an individual believes an outcome is caused by their
inherent characteristics, as opposed to external forces. Stable attributions are when individuals believe an outcome is long lasting, as opposed to brief, and global attributions are when individuals believe outcomes apply to many different situations as opposed to a specific situation. This theory extends to suggest that when positive things happen, feelings of hopefulness (and thus alleviation of depressive symptoms) often require internal, stable, or global attributions. In this study, we sought to explore to what extent undergraduate and graduate researchers make internal, stable, and global attributions when explaining the link between aspects of research they encounter and the exacerbation and alleviation of their depressive symptoms.

Study Design: We conducted a national semi-structured interview study of 74 science students with depression representing 60 institutions across the U.S. (50 graduate students and 24 undergraduate researchers). In the interviews, we addressed the following research questions:

RQ1: To what extent do students make internal (or external), global (or specific), and stable (or dynamic) attributions when explaining why failure, negative reinforcement, a lack of guidance, and isolation exacerbate symptoms of depression? RQ2: To what extent do students make internal (or external), global (or specific), and stable (or dynamic) attributions when explaining why success, positive reinforcement, guidance, and belonging alleviate symptoms of depression?

Analyses and Interpretations: We developed a coding rubric to identify instances of internal, external, global, specific, stable, and dynamic attributions of negative and positive events in research. Two researchers achieved interrater reliability using the rubric (K=0.95) and one researcher coded the remaining interviews to identify instances of students making internal, stable, and global attributions when discussing the exacerbation and alleviation of their depressive symptoms in the context of scientific research.

Every participant demonstrated internalizing, globalizing or stabilizing negative events in research when describing why an event exacerbated their symptoms of depression during the interview. Internal attributions were most commonly responsible for the link between a negative event and exacerbation of depression. For example, students would describe that their experiment failed because they are inherently bad at science or research. This thinking ultimately led to exacerbation of depressive symptoms. Conversely, students most commonly described stabilizing a positive event in research, or perceiving that the positive occurrence was likely to be long-lasting, which alleviated their depressive symptoms. For example, students would highlight that feeling a sense of belonging in the lab lessened their depressive symptoms, largely because they knew their lab mates would always be there for them in times of need.

Contribution: This study served as a proof of concept for the application of Hopelessness Theory of Depression to undergraduate and graduate research experiences. It demonstrates how clinical psychology theories can be applied to educational settings to better understand student experiences in college science.

Unlocking Opportunities: Enhancing Scientific Research Cultural Capital (SRCC) in Introductory Biology Students through Professional Development Workshops.

Eric Pennino (California State University, Sacramento)*; Andrea Palacio (California State University, Sacramento); Catherine Ishikawa (California State University, Sacramento); Kelly McDonald (California State University, Sacramento)

Abstract:
Study Context:
Undergraduate research experiences (UREs) are high-impact practices that provide students with a variety of benefits, including clarification or confirmation of career plans, improved critical thinking skills, and a greater likelihood of graduating with a STEM degree (Lopatto, 2007; Bowman & Holmes, 2018; Ishiyama, 2002; Ishiyama, 2002). Despite the evident advantages, many students face barriers to obtaining these limited opportunities. Cooper and colleagues (2021) build on Pierre Bourdieu’s theory of capital (Bourdieu, 1986) to describe the importance cultural capital plays in a student’s ability to obtain a research position. They describe scientific research cultural capital (SRCC) as a student’s awareness, understanding, and knowledge about the research enterprise that can help them obtain a research experience. Guided by the SRCC framework, our study investigated the intrinsic SRCC of introductory-level biology students from a four-year minority-serving university (FYU) and a community college (CC). We compared students’ knowledge, awareness, perceptions, and interests in UREs, and based on our findings, designed two in-class professional development workshops (“Research Workshops”). The Research Workshops aimed to enhance introductory biology students’ understanding of the nature of UREs, the benefits associated with participating, and the best practices for identifying and securing research experiences, with the ultimate goal of leveling the playing field for students aspiring to gain access to these opportunities. Finally, we examined the impacts of the Research Workshops on students’ SRCC and interest in pursuing UREs after engaging in the workshops.

Workshop and Research Design:
We developed two sequential Research Workshops using an iterative, data-informed strategy. In Fall 2021, we used a modified version of the URE-Mentoring, Awareness and Perceptions Survey (URE-MAPs; Rodríguez Amaya et al., 2018) that contains Likert-type items to gauge students’ experiences, awareness, and perceptions of UREs. We added the open-ended questions “Are you interested in participating in research as an undergraduate? Why or why not?” We conducted follow-up student interviews with questions to determine how students arrived at their survey answers. Data collected from these instruments guided the selection of specific topics to address in the workshops and confirmed that both FYU and CC students could benefit from similar content. In Spring 2022, we ran the Research Workshops at the FYU, administered the modified URE-MAPs surveys at the beginning (before the workshops) and end (after the workshops) of the semester and conducted end-of-semester student interviews. Data were used to make final adjustments to the workshop designs (Pennino and McDonald, 2024).

We implemented and evaluated the finalized Research Workshops in Fall 2022 and Spring 2023. Each workshop was approximately 30 minutes long and utilized think-pair-share activities, whole class discussions, and featured student speakers who shared their diverse research experiences with the class. The first workshop occurred before week five and the second between weeks eight and eleven of the semester.

We used a mixed-methods approach to evaluate the efficacy of the workshops and assess changes in student interest in participating in UREs. In Fall 2022 and Spring 2023 at the FYU and CC, we administered the pre and post URE-MAPs survey and conducted whole class focus groups according to the small group analysis technique (Coffman, 1998; Mordacq et al., 2017). In the Focus Groups, we posed question prompts to the class and gave students time to individually record their answers before sharing in small groups and in a whole-class discussions. Question prompts included: “Have your attitudes about undergraduate research changed over the semester? In what ways and why?” and “What was the most important thing you learned from the workshops and how might you utilize this in the future?” Students’ written
responses were collected and the whole class discussions were recorded and transcribed.

In Fall 2023, we administered the pre- and post-URE-MAPs surveys to students from an introductory biology course at the FYU who did not receive the workshops or focus groups (non-intervention group). The URE-MAPs was also administered at a single timepoint to students in a mid-level and an advanced course at the FYU, who did not receive the workshops, to determine if they were gaining knowledge, awareness, and perceptions of UREs as they progressed through the degree program through mechanisms distinct from our intervention. These data will serve as a baseline for comparison to future cohorts of mid- and advanced-level students who participated in the workshops during their introductory courses.

This project was completed under the IRB#19-20-289.

Analyses and interpretation:
An Exploratory Factor Analysis of the FYU Likert-type items on the URE-MAPs resulted in the formation of the Student-research Awareness construct, which included items about students’ awareness of URE opportunities and research activities they can participate in (e.g., research symposia). There was a statistically significant increase (p = 0.037) in Student-research Awareness scores for the students who participated in the Research Workshops, which was not observed in the non-intervention group. Descriptive statistics of Likert-type response in mid-level and advanced courses indicated that only 20-30% of these were aware of research opportunities and activities in the Student-research Awareness construct. These percentages were only marginally higher when comparing the same survey items to the introductory students who had not received the intervention.

Two researchers used an iterative, open coding, qualitative method to code open-ended URE-MAPs survey responses and students’ individually written focus group reflections. The recorded and transcribed whole-class discussions were used as a secondary data source to augment written responses to focus group prompts. Analysis of match-paired responses to the question “Are you interested in participating in research as an undergraduate?” was used to determine what effect the workshops had on students’ interest in participating in research. Chi-squared results revealed that FYU students who participated in the workshops (intervention group) were more likely to have a positive change in their interest in URE participation than students in the non-intervention group (X2 = 7.12; df = 2; p-value = 0.028). Multinomial logistic regression revealed that FYU students in the intervention group had approximately five times greater odds of experiencing a positive change in their interest in participating in UREs compared to students in the non-intervention group. Furthermore, compared to female students, males had approximately two and a half times higher odds of experiencing a “positive change.”

Analysis of students’ written responses to the focus group question “Have your attitudes about undergraduate research changed over the semester?” revealed that 56% of FYU and 69% of CC students had a positive attitude change towards undergraduate research, citing an increased awareness of URE opportunities, feeling that research was accessible, or gaining a deeper understanding about UREs and their benefits as the reason for this shift. While there were nuanced differences in the percentage of students who had attitude changes across institutions, FYU and CC students provi

Access to Nature’s Laboratory: Disabled Experiences in Ecology Fieldwork.

Ariel J Chasen (UT Austin)*; Sean Griffin (Lady Bird Johnson Wildflower Center); Shalene Jha (UT Austin)
Abstract:
Study Context: Fieldwork is a fundamental component of almost all natural science disciplines, as it allows students to gain critical hands-on experiences and apply theoretical knowledge to real-world problems in disciplines such as marine sciences (Scott et al., 2012) and ecology (Klemow et al., 2019). However, disabled students are underrepresented in fieldwork-heavy sciences due to barriers like inaccessible sites and limited accommodations and funding for adaptive tech (Carabajal et al., 2020). Thus, there is a critical need for research to understand how fieldwork can be made more accessible to disabled scientists.

This study is guided by theoretical frameworks of Critical Disability Theory (Meekosha & Shuttleworth, 2009), and Mapping Access (Hamraie, 2018). Critical Disability Theory (CDT), posits that disability is not an inherent trait of an individual but rather a social construct that is a result of an able-bodied society failing to consider the diverse needs and abilities of individuals. From a critical disability perspective, disability arises due to complex environmental, social, and political factors that are malleable across time and place (Annamma et al., 2013; Berghs et al., 2016). In the context of this study, CDT serves as a framework to analyze existing field-focused training strategies that often neglect equitable learning opportunities for student researchers with disabilities (Schalk, 2017).

Research Design: This study asks the following research questions: (I) What barriers do disabled individuals encounter when training in ecological fieldwork? (II) How do barriers vary depending on site characteristics, task requirements, and disability categorization? And (III) How can planning for fieldwork be reimagined to account for a diversity of access needs? Addressing these questions will allow us to develop audit tools for assessing accessible research spaces.

In this study, data collection methods involved utilizing three actual field sites, each carefully selected to encompass a wide spectrum of ecological attributes including ground cover and elevation, sun exposure, and distance from pathways. Each field task was also designed to approximate realistic ecological field tasks cited in current literature. The research employed cognitive interviews conducted with disabled individuals (n=35) while undertaking educational fieldwork tasks such as soil and microorganism sampling, air quality monitoring, bird watching, and vegetarian quadrant surveys. Data collection took place in three stages. During the first stage participants reflected on their prior experiences as disabled individuals in STEM and within fieldwork settings. During the second stage, they participated in fieldwork activities at the Lady Bird Johnson Wildflower Center, giving their thoughts on accessibility while working. Finally, participants gave reflective feedback in a focus group setting after having completed their fieldwork task. Data were collected via audio recording, field notes, and artifact collection.

Analysis and Interpretation: Thematic analysis of field notes and interview transcripts was employed for analysis. We categorized recurring themes and associations between environmental features, task characteristics, and experiences described by participants. Deductive coding methods also incorporated the principles of UDI (Burghstahler, 2001) to identify environmental constraints of the participant's experiences.

Our findings showed that disabled individuals perceived environmental barriers, communication barriers as well as perceptive and approach-based barriers to fieldwork. Reflective discussions with participants revealed that when engaging in ecology fieldwork, participants fear feeling "othered" and assigned as "non-scientists." They were more likely to seek out accommodation and meet access needs when these considerations were built into
the environment and fieldwork protocols. For example, one participant stated, “Asking for a bench makes me feel like an outsider but not asking for one makes it so I can’t engage, there’s no win”. To demonstrate the trustworthiness and credibility of the analysis, we triangulated multiple data sources and completed member-checking with study participant co-researchers (Guba & Lincoln, 1994).

Contribution: This study contributes significantly to the literature base in biology education by identifying specific access needs in field research and developing use-inspired solutions. It is pioneering in its approach, being among the first to prioritize the voices of disabled scientists during biology fieldwork. Its innovative nature and emphasis on inclusivity make it likely to be of general interest to SABER attendees. Furthermore, the study provides clear implications for teaching, learning, and research in biology by addressing the often-overlooked accessibility challenges in fieldwork and proposing tangible strategies for improvement.

**Experimental design skills can be improved using modular guided inquiry activities.**

Justin Fendos (Xian Jiao-tong Liverpool University)*

**Abstract:**

**Study Context:** Competence in experimental design (ED) requires proficiency in both evaluation and synthesis. Simply put, learners must be able to identify the strengths and weaknesses of a research design created by others while also being able to devise their own. Since ED necessitates the consideration of many complex pieces of interconnected and esoteric information, it is often regarded as the most difficult science process skill, a challenge affecting all science students, irrespective of age and nationality (Broadbent and Poon 2015; Crowe, Dirks, and Wenderoth 2008; Stefanou et al. 2013). Over the last two decades, a range of instruments have been devised to measure competence in either ED evaluation (Deane et al. 2014) or synthesis (Dasgupta, Anderson, and Pelaez 2014; Sirum and Humburg 2011). Despite these advancements and the universal need to develop ED skills, there remains a paucity of literature describing specific learning activities with established benefit to ED development.

**Study design:** Work by Blumer and Beck (2019) reported improvements in ED when undergraduates learned through guided inquiry (GI). Unfortunately, this study was conducted across multiple institutions, each operating different course variants, making it unclear which GI features were responsible for the favorable outcomes. To elaborate on this work, a series of modular GI activities was developed and implemented over a six-year period across three undergraduate life science contexts: one in China (n = 240) and two in South Korea (n = 246). Each activity was designed to exhibit the three defining features of GI (Halmo et al. 2020): 1) scaffolds that help students understand and organize new concepts and terminology; 2) collaborative tasks that facilitate the iterative practice of these ideas in a constructivist manner; and 3) a student-centered learning process in which instructors adopt a support role rather than a didactic one. To determine the efficacy of new GI activities, several assessments were used, including BEDCI (Deane et al. 2014), EDAT (Sirum and Humburg 2011), learner surveys, and focus groups.

**Analyses and interpretations:** The GI activities developed in this work were found to improve competence in both ED evaluation and synthesis by familiarizing students with an organized framework of common ED components. This framework facilitated the collaborative practice of ED components across diverse science topics. Results in the Chinese context demonstrated research-intensive CURE participation alone yields only minimal improvements in ED,
highlighting the need for ED-specific programming. Results in the Korean context demonstrated ED acquisition speed can differ significantly between cohorts, indicating the need for context-specific implementation. The latter results also demonstrated GI activities can be used as a preparatory curriculum, improving performance in an ensuing primary literature course. Surprisingly, the long-term retention of ED skills depended significantly on the length of inactivity students experienced between initial learning and subsequent exposure to new ED tasks. This indicated the sustained application of ED skills over an extended period is likely a key consideration for successful retention.

Contribution:
The results described above expand on our mechanistic understanding of ED skill acquisition, supporting the notion that ED evaluation and synthesis are best conceptualized as amalgamations of many simpler skills, each trainable in a targeted manner using modular GI activities. This work offers a useful model for the design of similar implements aimed at improving ED or other science process skills, with the achieved insights being broadly applicable across STEM contexts.

Session 3_D
A Breadth Course Model Fostering Equitable Science Connection through Challenge-Based Learning.

Haider Ali Bhatti (University of California, Berkeley)*

Abstract:
Short summary (TL;DR)
This study presents compelling evidence for the effectiveness of Challenge-Based Learning (CBL) in promoting equitable science connection among diverse undergraduate students. Using the Tripartite Integration Model of Social Influence (TIMSI) framework, we assessed pre/post changes in Science Identity, Science Self-Efficacy, and Internalization of Scientific Community Values in nearly 500 students from over 40 majors after participating in a course called Bioinspired Design. We saw significant growth in science connection development with a large effect size ($\eta^2 = .211$), challenging the notion that such growth requires extensive intervention time or is specific to certain demographic groups. Key course elements driving these results included interdisciplinary team projects, engagement with scientific literature, and a final design showcase where students presented novel bioinspired solutions to societal challenges. We observed significant gains in Science Identity and Science Self-Efficacy across all demographic groups, with no differences based on gender, underrepresented minority status, or first-generation status. This research offers a scalable model for undergraduate STEM education reform, showcasing how interdisciplinary, challenge-based courses can foster meaningful science connection for both STEM and non-STEM students alike. By reimagining science connection as an ongoing process, this study provides crucial insights for broadening participation in science and cultivating a more STEM-enriched society.

Complete Abstract

1. Study Context:
The need to foster equitable science connection among diverse student populations is crucial for harnessing the competitive advantages that diversity brings to innovation in STEM (AlShebli
et al., 2018; National Academy of Engineering, 2015). However, traditional undergraduate STEM courses often struggle to promote science connection equitably, with measures of integration often decreasing or remaining stable as students progress (Estrada et al., 2019; Seymour & Hunter, 2019). This study examines the impact of a Challenge-Based Learning (CBL) course, Bioinspired Design, on cultivating science connection among 180 undergraduate students from over 40 majors in a single semester.

We employed the Tripartite Integration Model of Social Influence (TIMSI) framework (Estrada et al., 2011) to assess changes in Science Identity (SciID), Science Self-Efficacy (Eff), and Internalization of Scientific Community Values (Val). This framework has been primarily used in longitudinal science training programs and formalized research experiences (Estrada et al., 2021; Newell & Ulrich, 2022). Our study expands its application to a large-enrollment, interdisciplinary breadth course open to all students, representing a new type of learning environment that diverges from previous TIMSI studies. The Bioinspired Design course exemplifies key CBL criteria, engaging students in collaborative identification of biological principles to develop solutions for societal challenges. This approach aligns with calls for engaging both STEM and non-STEM students in meaningful scientific inquiry to develop a scientifically literate citizenry capable of tackling future socioscientific issues (Ballen et al., 2017; Gormally & Heil, 2022).

2. Study Design:

We utilized a pre/post survey design, employing repeated measures ANOVAs, ANCOVAs, and paired t-tests to evaluate the equity of outcomes across diverse demographic groups. The survey, adapted from Estrada et al. (2011), measured SciID, Eff, and Val through Likert scale items. Data was collected over five spring semesters (2019-2023), spanning pre-, mid-, and post-pandemic periods with varying instructional modalities.

We tested three main hypotheses:

1. Nondominant identities hypothesis (H1): Our CBL course will promote equitable outcomes in SciID, Eff, and Val development regardless of students' gender, underrepresented minority (URM) status, or first-generation status.

2. Academic paths hypothesis (H2): Our CBL course will effectively promote science connection for all students, regardless of their disciplinary identity, class status, or the specific semester in which they take the course.

3. Overall gains hypothesis (H3): The Bioinspired Design course will lead to significant pre/post improvements in science connection, as measured by individual and collective SciID, Eff, and Val development.

These hypotheses were tested using a combination of statistical analyses, including Demographic Group RM ANOVAs, ANCOVAs, Overall RM ANOVAs, and item-level paired t-tests.

3. Analyses and Interpretations:

Our analyses revealed largely equitable outcomes across demographic variables for all three constructs in the repeated measures ANOVAs. ANCOVA results confirmed equitable outcomes for most demographic groups, with exceptions in SciID for STEM/Non-STEM majors and Class Status. These findings suggest that our CBL approach effectively promotes certain aspects of science connection in diverse, interdisciplinary classroom settings within a single semester.
Statistically significant improvements were observed in both Eff (large effect size, $\eta_p^2 = .176$) and SciID (small-to-medium effect size, $\eta_p^2 = .039$), while Val remained stable. These results contrast with typical decreases or stability observed in traditional undergraduate STEM courses (Estrada et al., 2019; Seymour & Hunter, 2019). Compared to other courses, our CBL approach showed more substantial and equitable gains in SciID and Eff. The lack of significant change in Val aligns with previous research (Cole & Beck, 2022) and suggests that this construct may require longer-term interventions to shift.

Item-level analyses revealed that all eight Eff items showed statistically significant increases, with the largest effect size observed for confidence in developing novel technologies ($d = 0.620$). For SciID, significant increases were found in students’ sense of belonging to the scientific community and self-perception as scientists. These findings highlight the course’s effectiveness in fostering key aspects of science connection. Analysis of gains across various disciplines revealed that while all majors benefited, STEM majors showed slightly higher gains in SciID, suggesting a potential area for targeted support in future iterations.

4. Contribution:
This study makes several significant contributions to the field of biology education research:

1) It demonstrates the effectiveness of CBL in rapidly and equitably promoting science connection among diverse undergraduate students within a single semester.
2) It expands the application of the TIMSI framework to a new context: a large-enrollment, interdisciplinary breadth course open to all students.
3) It challenges the notion that developing science connection requires extensive intervention time or is specific to certain demographic groups, proposing instead that it be viewed as a continually developing process.
4) It offers a scalable and adaptable model for undergraduate STEM education reform, showing how interdisciplinary, challenge-based courses can foster meaningful science connection for both STEM and non-STEM students.
5) It provides insights into the differential development of SciID, Eff, and Val, suggesting areas for future research and course design improvements.

These findings have important implications for broadening participation in science and cultivating a more STEM-enriched society. By demonstrating that different types of students can develop key aspects of science connection in a short timeframe, this research offers a promising approach for creating more inclusive pathways for all students to meaningfully engage with science. Future research directions include longitudinal studies to examine the persistence of these gains, qualitative investigations to understand student experiences more deeply, and explorations of how to more effectively impact the Val construct within the CBL framework.

**Investigating the role of students’ achievement goals on their use of ChatGPT.**

Julia Mellary (University of Guelph)*; Rayan Kanaan (University of Guelph); Nathan Cozzi (University of Guelph); Tim Bartley (University of Guelph); Dan Grunspan (University of Guelph)

Abstract:
Study Context:
The recent widespread availability of generative-AI (GenAI) tools has disrupted undergraduate education. An approach commonly recommended to instructors to address student use of GenAI in their classrooms is to create course- and assignment-specific guidelines for use
(Foltynek et al., 2023). However, creating informed guidelines is difficult without a more robust understanding about how students use GenAI. While some students may use GenAI tools in a manner that clearly constitutes academic misconduct, others may use these tools in a manner which supports their learning. Understanding how students vary in their use of GenAI, and why, can help inform policies and practices that ensure students use this emerging technology to advance their learning.

We are examining whether students’ use of GenAI is associated with their achievement goal orientation (AGO). AGO is a context-dependent measure of what drives students’ motivations for achievement that separately considers ‘performance’ and ‘mastery’ based motivations (Harackiewicz & Elliott, 1993). Students with high performance orientations are motivated by a desire to demonstrate their competence, while students with high mastery orientations are motivated by a desire to learn and improve. Previous research has found that students with high mastery orientations are significantly less likely to engage in academic misconduct (Fritz et al., 2023). We hypothesize that students with performance orientations may be more inclined to use GenAI to complete assignments without further supporting their learning, whereas students with mastery orientations may use GenAI in a manner that supports the advancement of their knowledge.

Study Design:
To fill this gap, students in an introductory biology course independently completed practice exam questions from a physiology concept inventory (McFarlane et al. 2017) where they were encouraged to use ChatGPT. After completing this activity, we collected students’ test responses and their ChatGPT logs, including their prompts to ChatGPT and the answers provided by ChatGPT. To measure students’ AGO, we administered the AGO Questionnaire-Revised (Elliot & Murayama, 2008). We also collected student responses on self-reported GenAI use, perceptions about whether GenAI use constitutes academic misconduct, as well as demographic information and course grades. Complete data and consent were obtained from 292 students.

Analyses and Interpretation:
To understand how students used ChatGPT, we performed a content analysis of students’ ChatGPT logs. These ongoing analyses reveal that the majority of students relied exclusively on ChatGPT to complete the concept inventory, even if it led to incorrect responses on their practice exam. While this was the general trend, interesting variations in students’ use of ChatGPT emerged, which will be presented. In total, 23 students opted not to use ChatGPT, with the most common reasons given being ethical concerns, concerns surrounding privacy of personal data, and desire to complete the work independently.

We are also examining whether GenAI use is associated with AGO (mastery and performance orientations). Counter to our hypotheses, logistic regression results indicate that neither mastery nor performance orientations were associated with the odds that a student opted not to use ChatGPT due to the desire to complete work on their own. Once content analysis of the ChatGPT logs is complete, we will perform further regression analyses to understand the role of AGO on specific uses of GenAI, as well as the roles of student experience using GenAI and their perceptions about GenAI and academic misconduct. We will present the results of these analyses, and results from our content analysis about the depth of student engagement following the generated software responses, and factors influencing students’ decisions to abstain from using ChatGPT for this academic task.

Contribution:
This novel examination into students’ use of GenAI in academic settings goes beyond self-report and captures actual student GenAI use. Students’ use of GenAI to help them complete academic assessments is an issue faced by all post-secondary instructors across disciplines, thus understanding how students’ motivations influence how they use these tools is important to inform classroom policy and procedures.

Justice-oriented curricula positively impacts the development of undergraduate biology students' critical consciousness.

Sabah Elias (University of California, Davis)*; Brie Tripp (University of California, Davis)

Abstract:

STUDY CONTEXT

Extensive efforts have aimed to foster a paradigmatic shift towards justice within science and medical fields to mitigate healthcare inequities and increase representation in science (National Academies of Sciences, Engineering, and Medicine [NASEM], 2021, 2023). However, a significant portion of undergraduate science students lack education on how science and medicine perpetuate disparities and are unaware of ways to collectively act in solidarity with communities most affected by social injustice.

This study aimed to increase awareness among undergraduate biology majors on how injustice in medicine and science (re)produces health disparities and what can be done to advocate against injustice through the completion of justice-oriented curricula. We utilized Brazilian philosopher Paulo Freire’s framework of Critical Consciousness to guide this study, which is based on three tenets: (1) critical reflection—an awareness and critique of systems of oppression, (2) critical self-efficacy—motivation and confidence to create change against oppressive systems, and (3) critical action—advocating and acting in solidarity with those most affected by oppression (Freire, 1968). To our knowledge, no studies exist regarding the impact of justice-oriented curricula on undergraduate biology students’ critical consciousness, highlighting the significance of this study.

RESEARCH QUESTION

In what ways do justice-oriented curricula impact the development of critical consciousness among undergraduate biology students?

RESEARCH DESIGN

To address our research question, eleven undergraduate researchers from underserved backgrounds co-authored Social Justice in Science (SJS) case studies based on social injustice topics in which they had lived experience and/or were of interest to them. These cases were comprised of three sections: (I) pathophysiology of a particular disease, (II) a social justice portion that focuses on a related health disparity within a certain underserved population, and (III) an advocacy portion. Undergraduate students who completed these as coursework were tasked with reading primary literature and analyzing graphs and figures to answer questions throughout the case.

In Spring 2023, we implemented five SJS case studies in an advanced upper-division physiology course mostly comprised of pre-health majors at a R1 institution (n=224). At the end of the course, we invited students through a survey to participate in an interview study regarding their perceptions of the case studies. Interview questions probed their perceptions of learning about social justice in science classrooms, their awareness of health disparities before and after completing the cases, and their motivation in advocating against health injustice in
their future careers.

ANALYSES
During the first cycle/round of qualitative analysis, we selected 16% of the interviews that displayed the most diverse responses. We independently read and wrote down all salient ideas (i.e., codes) from the interviews and then collectively combined similar codes based on the three tenets of critical consciousness (i.e., critical reflection, critical consciousness, and critical action). The remaining codes unrelated to our framework were grouped based on similarity. These codes became our codebook to further analyze interviews. We repeated this process until no new codes were emerging from our data. This led to a finalized codebook. Two researchers coded another 30% of interviews to reach interrater reliability (IRR= 83%). Researchers then re-coded the interviews to consensus with the finalized codebook.

RESULTS AND INTERPRETATION
Of the 30 students interviewed, 100% reported an increase in aspects of their critical reflection and 63% indicated an increase in critical self-efficacy. Only one student met the level of critical action. All students indicated SJS case studies improved their science learning by solidifying content taught in class and increasing engagement through real-world scenarios. These findings indicate that justice-oriented curricula have the power to shape the development of undergraduate students’ awareness of oppressive systems and the motivation to act against these injustices. However, these findings also underscore the necessity of guiding students towards critical action, such as collaborating with local communities to effect change in their areas or participating in political groups dedicated to challenging unjust policies and systems. This emphasizes the importance of delving deeper into the creation and integration of justice-oriented curricula in undergraduate biology classrooms through partnerships with communities directly impacted by injustice.

CONTRIBUTIONS
This study provides evidence of the positive impact of justice-oriented curricula in science classrooms and ways in which these interventions shape the development of critical consciousness in undergraduate biology populations.

Alternative grading practices in Undergraduate STEM: a scoping review.

Emily L Hackerson (North Dakota State University)*; Tara Slominski (North Dakota State University); Nekeisha Johnson (North Dakota State University); John Buncher (North Dakota State University); Safana Ismael (North Dakota State University); Lauren Singelmann (Minnesota State University Mankato); Alexey Leontyev (NDSU); Alexander Knopps (North Dakota State University); Ariana McDarby (North Dakota State University); Jonathan J Nguyen (North Dakota State University); Danielle Condry (North Dakota State University); James Nyachwaya (North Dakota State University); Kathryn Wissman (North Dakota State University); William Falkner (North Dakota State University); Krystal Grieger (North Dakota State University); Lisa Montplaisir (North Dakota State University); Angela Hodgson (North Dakota State University); Jennifer Momsen (North Dakota State University)

Abstract:
Study Context: Traditional grading practices are increasingly recognized as perpetuating systemic inequities in education (Feldman, 2018). Because of this, alternative grading practices in STEM such as standards-based grading (SBG; Lewis, 2022), specifications grading (Nilson, 2014), and ungrading (Kohn & Blum, 2020) have emerged to more accurately reflect student learning (Schinske & Tanner, 2014; Townsley & Schmid, 2020; Clark & Talbert,
However, a lack of evidence of efficacy has contributed to continued confusion and skepticism.

Since research on the impact of alternative grading practices on student learning is currently limited, our interdisciplinary team used a scoping review to map the current state of the research and identify literature gaps (Arskey & O’Malley, 2005; Khalil et al., 2016; Miles, 2017). In our study, we used the Arskey and O’Malley (2005) Framework to (1) identify research questions, (2) identify relevant studies, (3) select studies, (4) analyze results, and (5) report results. Additionally, alternative grading practices are used across disciplines, so an interdisciplinary approach to our scoping review was essential to mapping the research across STEM.

Study Design: Stage 1: Identifying the research question. Through group discussions we developed three research questions: (1) what is currently known about the impacts of alternative grading practices on student outcomes across STEM disciplines, (2) what gaps currently exist in the body of research, and (3) is the research on alternative grading in STEM occurring in discipline- or methods-based silos.

Stage 2: Identifying relevant studies. Our interdisciplinary team of graduate students and faculty in Biology, Chemistry, Engineering, Physics, and Psychology searched applicable journals and databases for studies investigating alternative grading practices in these STEM disciplines. The initial search yielded 332 unique records.

Stage 3: Study selection. We limited included studies to peer-reviewed research done in the United States at the undergraduate level. After applying these criteria to the 332 records, our corpus consisted of 75 studies published between 1971 and 2023.

Analyses and Interpretations: Stage 4: Analysis of chosen studies. We coded each report for study context and characteristics. Study contexts included course delivery (online or in-person), course type (lecture or lab), course audience (STEM majors or non-majors), course level (introductory or upper division), course enrollment size, institution Carnegie classification, discipline, and name of alternative grading practice. Study characteristics included measured variables (e.g. student course performance), how measurements were made (e.g. survey, course grades), and whether the results were in support or against the indicated alternative grading practice.

Stage 5: Reporting results. The most common alternative grading practices across our corpus were SBG (n=18), mastery grading (n=16), and specifications grading (n = 14). Studies largely came from courses in Chemistry (n=21) and Engineering (n=30). We identified 179 variables measured across the 75 studies with the most common being student performance (n=74), representing student performance in a course or on specific assessments. Results were largely supportive (n=106) of alternative grading.

We found evidence of knowledge gaps, methodological gaps, and theoretical gaps in the alternative grading literature (Miles, 2017). A knowledge gap is implicated due to the limited number of studies (n=75) that represent some disciplines more than others. A large proportion of the variables reported in our corpus were measured using a survey designed by the researcher (n=36), making it impossible to compare outcomes across populations, implicating a methodological gap. Finally, we were unable to characterize the theoretical frameworks used by researchers - these were not included in many papers. This indicates a theoretical gap.
Contribution: Alternative grading practices are gaining popularity across STEM. However, the implementation of these practices seems to be outpacing the collection of empirical evidence of their efficacy. This review provides a picture of the current alternative grading practice landscape and provides insight into how the research community could move forward to support these practices empirically. We note that alternative grading practices are not universally defined and most of the studies lacked a rich description of the practices implemented; this impeded our ability to meaningfully group papers together to make broader claims about the state of the research. If alternative grading practices are to gain traction as an equitable and high-impact teaching practice, the community must develop clear definitions of the various practices and continue efforts to support these practices empirically.

Impact of Specifications Grading on Student Voice, Performance and Learning Strategies in Introductory Biology Classes.

Min Zhong (Auburn University)* & Jianwei Dong

Abstract:
As an innovative pedagogical approach, specifications grading (specs grading) features distinct components including explicit learning objectives aligned with assessments, pass/fail grading specifications, bundled assessments, and providing students with opportunities for exam retakes and assignment resubmissions (Nilson, 2015). Due to its ability to reduce grading inequity, specs grading has been adopted in some STEM classrooms (Tsoi et al., 2019; Katzman et al., 2021; Howitz et al., 2021; Suresh, 2023; McKnelly et al., 2023; Saluga, et al., 2023). Research evidence has demonstrated that specifications grading can benefit students by enhancing their ownership of learning, improving content understanding, and fostering a positive learning attitude (Katzman et al., 2021; Nilson, 2015). However, implementing specifications grading in large classrooms can be challenging for instructors (Howitz et al., 2021), as it requires significant time and effort to develop and communicate clear specifications for assignments. In fall 2023, I developed and implemented the specs grading intervention in two student-centered large introductory biology classes (N=380).

The objectives of this study are to assess students' attitudes toward learning in large enrollment introductory biology classes and to examine the potential influence of these attitudes on their high-order metacognitive skills and academic performance. Specifically, I aimed to answer the following research questions:

1. How does the specs grading influence the class grade distribution?
2. How does the specs grading impact students' high-order learning skills?
3. What are student awareness and feedback regarding the specs grading system?

This study used mixed methods to investigate the effects of the specification grading scheme in student-centered introductory biology classes from different aspects.

To measure how the specs grading system impacts class grade distributions, student grade data was collected from four consecutive semesters, from spring 2022 to fall 2023. The results showed a significant increase in class average grades, with a significantly increased number of As and Bs. To collect more student feedback about the different components of the specs grading system, I used an end-of-semester survey (Boesdorfer et al., 2018). The preliminary results showed that students reported improvements in their learning strategies when preparing for exams and retakes. They also expressed appreciation for completion-based assignments with revision opportunities. To measure the impact of specs grading on students’
high-order skills, I used the Metacognitive Awareness Inventory (MAI) as the instrument, with 52 items categorized into two dimensions: knowledge about cognition and regulation of cognition (Schraw and Dennison, 1994). I collected both pre- and post-semester data from the intervention semester (fall 2023) and a control semester (spring 2022) without specs grading intervention. The MAI data analysis is ongoing, and I seek to gain insights into the effectiveness of the intervention in promoting a positive learning experience, regulation of cognition, and class performance.

Despite positive outcomes, I received some negative feedback. First, from the survey data, students’ self-reported perception and appreciation of the specs grading semester remain low, indicating a potential awareness gap in freshman-level science classes, although the class average final grade was high. Despite variations in specs grading implementation in STEM classes, the classroom practices in this study exhibited similar challenges for instructors (Howitz et al., 2021; McKnelly et al., 2023), although the classroom dynamics have been observed to shift to more active discussions of content instead of focusing on grades. In addition to the class data, the instructor observed more complaints from both students and parents about the grading system after the semester ended.

In conclusion, instructors interested in implementing the specs grading system should be prepared for increased workload and cognitive load during the pilot semester. Providing data-informed transparent instruction about the specs grading system can help increase students’ perceptions, and seeking support beyond the classroom is essential due to the sensitivity of touching the grading system.
Concurrent Short Talks - Session 4

Session 4_A

Resistance Spotlights to learn about justice-oriented participation and reimagine disciplinary futures.

Sugat Dabholkar (Tufts University)*; Julia Gouvea (Tufts University); Kit/Kat Coburn (Tufts University); Lawrence Uricchio (Tufts University)

Abstract:
Scientist Spotlights (SS) are part of an equity-oriented intervention that is designed for students to reflect on the work of practicing scientists from communities that have been marginalized from STEM (Schinke et al., 2017). We examine the design and use of a subtype of spotlight assignments that we call Resistance Spotlights (RS) that feature disciplinary work in service of justice-oriented goals. RS feature researchers whose work aims to disrupt oppressive structures in the discipline and challenge past and present ideas that are rooted in oppressive eurocentric, white supremacist, heteronormative, patriarchal ideals. For example, in an RS assignment students reviewed and reflected on 1) an evolutionary biology article co-authored by Dr. Ambika Kamath that challenged heterosexual behavior as a baseline/normal condition in animals (Monk et al., 2019), and listened to a podcast (SSE Communications (n.d.)) in which Dr. Kamath talked about how her identities as a brown woman and a feminist were connected to her academic scholarship. In this study, we investigate how RS as compared with SS supported students in an undergraduate computational biology class in reflecting on disciplinary participation in connection with their own identities and possible futures.

As posited by situated theories of learning, students are always learning about disciplinary participation in connection with their possible futures in a discipline (Secules, 2019; Vakil, 2020; Yackel & Cobb, 1996). Through choices in which scientific discoveries are discussed in class, students can glean insights into the kinds of contributions through disciplinary participation that are considered valuable. And in learning about disciplinary participation students can also learn about themselves and how they might (or might not) fit into disciplinary communities (Estrada et al., 2016; Quan & Elby, 2016; Vakil, 2020). Prior research suggests that SS can expand students’ conceptions of who does science and if they want to do science (Schinske et al., 2017; Ovid et al., 2023). However, less attention has been paid to what students learn about the forms of disciplinary participation and what kind of science they envision themselves doing.

This work is part of a collaborative Design-Based Research (DBR, Design-Based Research Collective, 2003) project, which is argued to be a compelling methodology for advancing the field of Biology Education Research (BER) (Scott et al., 2020). Our data included written responses of 29 consented students to 6 spotlight assignments: 3 RS and 3 SS. We conducted a qualitative analysis of students’ written responses to spotlights using a combination of top-down and bottom-up coding approaches (Miles, Huberman & Saldana, 2014). Our coding captured ideas related to disciplinary content, connections to student identities and interests, and reflections on disciplines.

We found statistically significant differences between SS and RS in the proportion of responses coded for five categories: disciplinary content, researcher and student identity labels, disciplinary contributions that are valued by researchers, and critical consideration of
power in connection with disciplinary participation. A second round of bottom-up coding and thematic analysis revealed the differences in how students reflected on valued contributions through disciplinary participation. In the responses to RS, students reflected more on equity/justice-oriented contributions as opposed to reflecting on knowledge/technical advancements or applied advancements in the field. Overall, our analyses suggest that SS and RS assignments support different types of equity-oriented outcomes. While SS can support students to reconsider who can participate in STEM, RS can support students in critically reflecting on how STEM research is done and in making connections among their identities and possibilities for their own futures in the disciplines.

This work introduces a new subtype of Scientist Spotlights called Resistance Spotlights and presents how it can be used in addition to SS to support students in navigating valued contributions through disciplinary works and imagining. SS have been demonstrated to be effective in supporting marginalized students in seeing their future selves as participants in the disciplines, whereas this work shows how RS can be used as materials for all students to imagine possibilities of different forms of their future participation in disciplines to make the disciplines just and equitable. We propose that RS can support students in thinking about the allied-political struggle that also requires commitments from the people holding power within disciplines and people who are likely to gain more power because of their dominant identities (such as white, and male) as they become members of disciplinary communities to recognize ethical and political work as a core commitment of disciplinary communities (Calabrese-Barton and Tan, 2020).

“It’s been a process”: Biology instructor efforts to reform their undergraduate sex/gender curriculum to be more accurate and inclusive of trans-spectrum and intersex students.

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Abstract:
Study Context:
Society often defines sex using supposedly clear-cut, binary categories of male and female (Morgenroth & Ryan, 2021). However, categorizing individuals based on sex is complicated due to the incredible biological diversity and complexity across and within these categories (Fausto-Sterling, 2012; Gorelick et al., 2016). Further muddying the waters of an accurate and complete understanding of sex is gender essentialism - the theory that gender and gender roles are natural and biologically driven based on sex (Rhodes & Gelman, 2009) - which incorrectly conflates sex and gender and assumes character traits based on sex. Teaching both the diversity and complexity of sex and anti-essentialism narratives are necessary, both to ensure accurate scientific understanding (Coley & Tanner, 2012; Donovan et al., 2019; Schindel et al., 2016) and equity and inclusion (Hughes & Kothari. 2021; Maloy et al., 2022). Accurate and inclusive sex/gender education is particularly important in undergraduate biology, given many students take biology courses: 41% of STEM degrees are undergraduate biology degrees, and introductory biology courses are commonly required across STEM majors (National Science Foundation, 2014). Preliminary research demonstrates the way sex/gender are presented is oversimplified relative to the complexity in biology (Hubbard & Monnig, 2020; Štrkalj & Pather, 2021). Efforts at the K-16 level have called to make biology curriculum more accurate and inclusive to trans-spectrum (i.e., those whose experience of gender does not
match the sex they were assigned at birth) and intersex students (e.g., Long, Steller, & Suh, 2021; Zemenick et al., 2022). In the present study, we build on these efforts by investigating how biology instructors - who are working to be inclusive of the diversity of sex/gender - teach sex/gender in their undergraduate biology courses.

Research Design:
We investigated the following two research questions: (1) What trans-spectrum and intersex inclusive sex/gender teaching practices are instructors implementing in their biology courses?; and (2) What journey do instructors go through to implement these teaching practices? We used a multiple case-study approach, gathering multiple sources of data from four biology instructors who identified themselves to the research team as teaching using trans-spectrum and intersex inclusive practices (Cresswell & Poth, 2017). We used the instructor’s course materials to conduct stimulated-response interviews (Fox-Turnbull, 2009), inviting the instructors to respond to their own course materials and use them to facilitate further discussion about (1) the inclusive sex/gender teaching practices they used and (2) their journey to implementing these practices in their courses. We explored these ideas through the lens of Bank’s Four Levels of Integration of Multicultural Content framework (Banks, 2010), categorizing teaching practices according to the level to which sex/gender inclusivity was integrated throughout the course.

Analyses and Interpretations:
To analyze the course materials and interviews we used document analysis (Bowen, 2009) and iterative directed content analysis (Hsieh & Shannon, 2005), respectively. From the data, we noticed instructors used a variety of inclusive teaching practices, ranging from briefly featuring a trans-spectrum scientist in their course materials (Level 1) to overhauling the curriculum to center trans-spectrum and intersex inclusivity throughout the duration of the course through teaching sex/gender diversity as the rule rather than the exception, using exam questions to reinforce accurate sex/gender biology content, and educating students about puberty blocker use in adolescents with gender dysphoria (Level 3). To implement these practices in their classrooms, instructors described engaging in personal reflection and challenging gender essentialist narratives prior to and iteratively throughout implementation; we called this process “unlearning.”

Contribution:
While many frameworks focus on the inclusion of particular teaching strategies, our findings suggest the importance of further understanding the iterative unlearning process these instructors underwent prior to and during the implementation of trans-spectrum and intersex inclusive teaching strategies. We encourage biology instructors to consider their current sex/gender teaching practices, and we provide resources as a place to start this evaluation. For any instructors unsure about starting the process of reforming their sex/gender curriculum to focus on diversity and inclusion due to concerns of doing harm to their students during the instructor’s unlearning process (e.g., what if I say something wrong?), we argue the present harms of teaching sex/gender in an inaccurate and binary manner do more damage than implementing well-meaning, accurate, and inclusive trans-spectrum and intersex inclusive teaching practices.

Edited captions on recorded lectures make STEM courses more accessible for SWD.
Poorvi Datta (California State University San Marcos)*;
Mallory M Rice (California State University San Marcos); Laci Gerhart-Barley (University of California Davis)
Abstract:
Study context:
A smaller proportion of undergraduate students with disabilities (SWD) persist and graduate with their STEM majors than non-SWD (Hamrick 2021). Integrating captioned recorded lectures in STEM classrooms may increase accessibility to remedy this equity gap in line with Universal Design for Learning. However, the caption type on lectures can impact student experiences as auto-captions are less accurate than edited captions, which can pose issues in jargon-heavy STEM courses. From SWD’s perspectives, Deaf and Hard-of-Hearing students strongly prefer edited captions (Brett 2016), and students with learning disabilities display higher comprehension and grades when provided captions (Morris et al. 2016). However, SWD are not homogenous and the unique preferences of different disability subtypes (chronic health conditions, mental health/psychological disabilities, physical disabilities, vision loss) are not well documented.

Research Design:
Research questions:
To what extent do SWD prefer automatic or edited captions?
What rationales do students give for their caption preferences?
What disability-specific obstacles are impacted by caption inclusion and type in STEM courses?

To investigate how captions and caption type interact with disability-specific barriers to learning, we conducted 26 semi-structured interviews SWD. All interviews were conducted via Zoom. Interview transcripts were transcribed, de-identified to ensure confidentiality, and participants were assigned random pseudonyms. Emergent theme analysis was conducted using MAXQDA software. An initial codebook with emergent themes was developed from a random 25% subset (n = 6) of interviews. After coding another random 25% subset with the initial codebook, it was concluded that the themes developed were applicable to the rest of the data set. All interviews were coded to consensus.

Analyses and Interpretations:
Emergent themes demonstrated that SWD highly preferred the provision of captions and reported several benefits. Students shared that captions can address gaps in knowledge arising from inattention, they facilitate comprehension of jargon, and they enhance information retention simply because of their multimodal nature.

Building on this, participants demonstrated a hierarchical preference for captioning type; edited captions were highly preferable to automatic captions, which were preferable to no captions at all. This lay largely in the fact that errors in automatic captions created significant burden for SWD. For many participants, errors created new disability-specific obstacles (e.g. additional distractions to already distractible students) and/or misrepresented keywords or jargon, resulting in students learning incorrect information. Altogether, this not only diminished the benefits of captions but also often led to SWD facing additional disadvantages on top of existing barriers to learning. However, participants concurred that despite the burden that errors in automatic captions may create, they still preferred having captions available over having none. This allows students to decide for themselves, based on their individual access needs and abilities, whether this potential equity tool benefits them.

Contribution:
Understanding the captioning preferences of students with disabilities in STEM is key to
informing pedagogical changes that may foster inclusive learning environments in STEM classrooms so that a greater proportion of SWD persist and graduate with STEM degrees. Shifting responsibility away from SWD to request accommodations like captions and implementing more universally accommodating modes of instruction can aid undiagnosed students. It also does not force diagnosed students to disclose their disability status and lessens intersectional barriers associated with race, finances, gender etc., essential to interpreting Universal Design for Learning into STEM courses.

**Perceived inequities in STEM classes make them competitive.**

Sumitra Tatapudy (University of Washington Seattle)*; Ineeya Kayal (University of Washington Seattle); Madhumita Rajesh (University of Washington Seattle); Katerina Boukouzis (University of Washington Seattle); Rita Socko (University of Washington Seattle); Elli J Theobald (University of Washington)

Abstract:

Study Context:
Despite ongoing efforts to enhance STEM education and improve student outcomes, STEM fields continue to lack equity, inclusion, and diversity. The disproportionate attrition of minoritized students remains a pressing issue in higher education, primarily due to the psychological impact of performance rather than interest or preparedness (Stanich et al., 2018). Minoritized students who switch out of STEM majors often cite competition as a reason (Strenta et al., 1994). Contrary to the belief that competition fosters increased productivity, it tends to yield negative effects in learning environments (DiMenichi & Tricomi, 2015), disproportionately affecting minoritized students in STEM (Posselt & Lipson, 2016). For instance, women perform worse on memory tasks (LaCosse et al., 2016) and experience feelings of depression and lower self-confidence compared to their male peers due to competition (DiMenichi & Tricomi, 2015). However, competition is understudied, particularly concerning what it means for minoritized students, the factors influencing a competitive STEM environment, and how competition affects students' sense of belonging.

Study Design:
In this study, we sought to understand how undergraduate students from minoritized groups perceive competition in STEM classes. Specifically, our research questions were: (1) Does competition create a sense of in-group and out-group? (2) What is the impact of competition on students' sense of belonging? To explore students' perceptions of competition in STEM and its effects, we conducted semi-structured interviews with 25 minoritized students enrolled in a large, introductory biology course offered at a public R1 university in the Pacific Northwest during Fall 2022 and Winter 2023. This course featured a non-competitive grading structure. Based on demographic information obtained from a class experience survey we administered, we specifically invited students who identified as African American/Black, Hispanic/Latinx, Alaskan Native/Native American, Native Hawaiian/Pacific Islander, or first-generation, via email, to participate in interviews. Interviews lasted for 60 minutes and were analyzed using inductive coding based on a grounded theory approach. Two authors independently coded each student interview, while a third author reviewed the codes to ensure alignment with agreed-upon usage and provided perspective to facilitate consensus when needed. After all interviews were coded, we grouped codes thematically and organized them to generate theory.

Analyses and Interpretations:
We used the Theory of Opportunity Hoarding as a lens to understand the interplay between competition, inequities, and sense of belonging. According to the Theory of Opportunity
Hoarding, the privileged in-group actively monopolizes resources and opportunities, perpetuating inequality and excluding marginalized out-groups. Our data analysis revealed a recurrent theme: when students labeled a class as "competitive," they were referring to disparities – specifically, disparities in prior preparation, understanding, access to resources, time, and ultimately, success. Minoritized students perceive distinct out-groups and in-groups in STEM learning environments, and the unequal distribution of opportunities and resources between these groups shapes their perceptions of inequities. Additionally, we found that that competition stemming from perceived inequities led students to doubt their competence, resulting in a lower sense of belonging. The perception of in-group hoarding, resulting in limited access to essential resources and opportunities for success, ignites a sense of competition among out-group students, further fracturing their sense of belonging in STEM classes.

Contribution:
In order to retain minoritized students in STEM, it is critically important to understand and address the reasons that make STEM classes competitive. In this study, we center the voices of minoritized students to understand their perceptions of competition in STEM introductory class environments. Notably, this study uniquely found that when students label a class as competitive, they are expressing perceptions of underlying inequities. The identification of a fractured sense of belonging as a result of a competitive class environment highlights the urgent need for interventions to promote a non-competitive, equitable class environment in STEM education. Recognizing that inequities and competition in STEM are systemic issues with instructors, departments, and universities as agents for change, we emphasize the necessity for collaborative efforts and systemic reforms to address inequities to foster equitable and non-competitive learning environments.

Making space for meaningful learning: Retesting in Introductory Biology.

Tara Slominski (North Dakota State University)*; Jennifer Momsen (North Dakota State University)

Abstract:
Study Context: The majority of undergraduate students in the U.S. are nontraditional (NT), with 74% of students reporting at least one NT characteristic (e.g., delayed enrollment, attends college part time, works 35+ hours per week, financially independent, has dependents, etc.; NCES, 2015). Despite this reality, the design of gateway STEM courses predominantly caters to the traditional student persona. This mismatch in course structure may exacerbate existing disparities and disproportionately affect NT students' persistence, retention, academic performance, and overall success metrics. Similarly, rural undergraduate students encounter comparable hurdles. Reports indicate notably lower graduation rates among rural STEM students in contrast to their urban counterparts.

Systemic classrooms practices, like grading and testing practices, have largely been unexplored despite their propensity to create inequity. This mixed method, exploratory study seeks to better understand the impact of testing policies on student outcomes in undergraduate biology courses. Typically, traditional grading approaches penalize mistakes, giving students only one attempt to demonstrate their learning on exams. However, meaningful learning can happen by way of making mistakes (Metsalfe, 2017). We are interested in whether retesting can promote learning while also mitigating the challenges NT, working, and rural students experience in undergraduate biology classrooms.

Research Design: We surveyed students in an Introductory Biology course at a large,
Midwestern R1 institution in Fall 2023. Our survey consisted of 9 items designed to determine NT, working, and rural status. In this focal course, final grades were primarily determined by student performance on 12 tests (over 85% of final grade). Students were allowed to reattempt tests without penalty. We also obtained gradebook data for all participants enrolled in our focal course to address the following research questions: Do NT, working, or rural students experience different levels of initial success on Introductory Biology tests compared to their traditional, nonworking (NW), or nonrural peers? If differences in initial test success exist across demographic groups, will those differences be mirrored in final course grade distribution in a course that allows students to retest without penalty?

We also conducted a focus group with 5 students enrolled in our focal course to gain insight into students’ perceptions of and experiences with retesting to begin to understand how the ability to retest may impact students’ beliefs, behaviors, and intentions to persist in a gateway biology course.

Results and Interpretations: Of the 84 students who completed our survey (RR = 0.76), 36% reported at least one NT indicator, 57% were working, and 38% had a rural background. Results of chi-square test revealed that, collectively, the first test attempts made by NT students had a lower proportion of success than the attempts made by their traditional peers (p < 0.01). The difference in initial success between working and NW students was also significant (p < 0.001) - NW students collectively had a higher rate of success compared to students working fewer than 20 hours per week (Bonf. adj. p < 0.05) and compared to students working between 20 and 35 hours per week (Bonf. adj. p < 0.01). There was no difference of initial success between rural and nonrural students. Despite a lower rate of initial success, there was no difference in final grade distribution between traditional and NT students, nor was there a difference between working and NW students, suggesting retesting practices may be well suited to support NT and working students as they balance the many expectations found in our syllabi with their responsibilities elsewhere in our community.

Focus group participants reported spending time and effort revisiting course material and instructor feedback to improve their understanding of the concept prior to retesting. Overall, focus group analysis provided qualitative evidence advocating for retesting practices as means to promote meaningful learning and create a more equitable course environment.

Contribution: Grades have the potential to influence all aspects of the student experience, spanning from small moments in a single classroom to degree completion and postbaccalaureate opportunities. Few studies have explored the impact of alternative testing and grading strategies in undergraduate STEM classrooms and even fewer are situated in the context of biology. Further, NT, working, and rural students are underrepresented in biology education research and often not included in discussions about underserved populations in undergraduate biology. The insights gleaned from this work are a first step in understanding why NT, working, and rural students are leaving biology and STEM fields and lays the groundwork for future research needed to inform instructional and programmatic change.
Reservation and Non-Reservation Students’ Transition into College STEM.

Brandon M Mansfield (Brigham Young University)*; Dallin Anderson (Brigham Young University); Elizabeth G Bailey (Brigham Young University)

Abstract:
Study Context: Native Americans are underrepresented in Science, Technology, Engineering, and Mathematics (STEM) fields (Cajete, 2021; Estrada et al.,2022). Notwithstanding proposed solutions to this marginalization, Native Americans continue to encounter many barriers and challenges when transitioning into college STEM courses, including lack of support, inadequate preparation, and school expenses (Barlow & Villarejo, 2004; Turner et al., 2022). Previous research on this transition has largely investigated Native Americans broadly, without studying possible differences between those with reservation and non-reservation backgrounds. The research that has considered reservation background looked at transition into higher education in general (e.g., Huffman, 2003), so more research is necessary in STEM specifically.

Social Cognitive Career Theory (Lent et al. 2000) suggests that environmental influences as well as race/ethnicity impact learning experiences and actions as individuals choose fields and persist (or not). Thus, we hypothesized that reservation versus non-reservation background would be an important environmental influence that could impact how Native Americans experience the transition into college STEM.

Study Design: Our qualitative research will address the question, what experiences differ between reservation and non-reservation Native Americans during their transition into college STEM curriculum? We conducted semi-structured interviews with about ten Native American students who are majoring in STEM or are enrolled in college STEM courses. With their consent, all interviews were recorded, transcribed, and analyzed. We asked them questions regarding their experiences in STEM courses, barriers to success, and supports they received when transitioning into STEM. We selected a qualitative approach for this project, as the sample size of Native American STEM majors is comparatively small, and this would be very effective in deepening our understanding of their perspective.

Analysis and interpretation: We have chosen an iterative, inductive thematic network analysis method (Attride-Stirling 2001). We start by looking for recurring themes and essential ideas from each transcript. As a team, we then discuss keywords or ideas we want to look for line by line. Our team then individually codes the transcripts line by line using MAXQDA before, meeting to reach a consensus on differences. We then go through similarly coded passages repeatedly to develop final themes. Preliminary results suggest that those growing up near a reservation experience more identity appreciation and frustration than those with a non-reservation background.

Contribution: Our research will be of special interest to STEM instructors and administrators. Based upon the interviews, Native American students greatly appreciate more outreach from STEM instructors. We will not only provide enlightenment regarding Native Americans’ difficulties transitioning into STEM but also invaluable insights regarding their strengths that can open opportunities for more discussions and research. This research will also contribute towards the continuation of strategy development to help mitigate the college STEM transition process of both reservation and non-reservation Native American backgrounds. Native
American tribes request more STEM professionals of their own (Howard & Kern, 2019), and our research helps contribute to this cause.

**Does Instruction-First or Problem-Solving-First Depend on Learners' Prior Knowledge?**

Cheng-Wen He (University of Georgia)*; Logan Fiorella (University of Georgia); Paula P. Lemons (University of Georgia)

**Abstract:**

**Study Context:**

Researchers in cognitive science have provided empirical evidence for the benefits of explicit instruction as well as opportunities for active engagement in problem solving (Kapur & Bielaczyc, 2012; Sweller et al., 2011). Yet, an unresolved debate is whether students should receive explicit instruction before or after engaging in problem solving (Kalyuga & Singh, 2016; Kapur, 2014). Proponents for instruction-first (I-PS) approaches claim that explicit instruction should precede problem solving to avoid cognitive overload, especially for students who have lower prior knowledge (Sweller et al., 2011). Proponents favoring problem-solving-first (PS-I) approaches assert that problem-solving activities should precede explicit instruction to better prepare students for future learning, regardless of students’ prior knowledge levels (Kapur, 2016; Schwartz & Martin, 2004).

One particular aspect of the debate between I-PS and PS-I proponents focuses on the role of prior knowledge in moderating the impact of these two approaches. It is unknown how students’ level of background knowledge influences the comparative effects of these two instructional sequences. The present two-experiment study aims to address this gap in the literature by comparing the effects of I-PS and PS-I on students with two different levels of prior knowledge.

**Study/Research Design.**

This study included two experiments comparing the effects of I-PS and PS-I on students’ understanding of a consistently challenging concept in undergraduate biology education: the physical basis of noncovalent interactions (Loertscher et al., 2014). Experiment 1 focused on introductory biology students who have relatively low prior knowledge, and Experiment 2 targeted upper-level biochemistry students who have relatively high prior knowledge.

We tested two competing hypotheses about the effects of pedagogical sequences. According to the cognitive load hypothesis, I-PS should be more effective than PS-I for students with lower prior knowledge (Experiment 1), but PS-I should be more effective than I-PS for students with higher prior knowledge (Experiment 2). According to the productive failure hypothesis, PS-I should be more effective than I-PS across levels of prior knowledge (Experiment 1 and Experiment 2).

We recruited 367 students in an introductory biology course for Experiment 1 and 138 students in a biochemistry course for Experiment 2. We randomized the participants into I-PS and PS-I groups for each experiment. The I-PS group followed the following procedure: pretest, explicit instruction, problem solving, and posttest. The procedure for the PS-I group followed this sequence: pretest, problem solving, explicit instruction, and posttest.

**Analyses and Interpretations.**

Experiment 1
A non-parametric Quade ANCOVA was conducted to compare the I-PS and PS-I students’
posttest performance after accounting for the influence of prior knowledge. The results showed that PS-I students significantly outperformed I-PS students, $F(1, 365) = 7.18, p = .008, \eta^2 = .019$. The results suggest that PS-I leads to better performance, albeit with a small effect size.

Experiment 2
An ANCOVA was conducted to compare the I-PS and PS-I biochemistry students’ posttest performance after accounting for the influence of prior knowledge. The results show that the I-PS students significantly outperformed the PS-I students, $F(1, 136) = 4.51, p = .036, \eta^2 = .033$. The results suggest that I-PS leads to better performance, albeit with a small effect size.

Contribution.
The findings from Experiment 1 support the productive failure hypothesis but not the cognitive load theory. Based on the proposed mechanism for the effectiveness of productive-failure instruction, the preparatory problem-solving activity in experiment 1 might have activated the PS-I group’s prior knowledge, increased their awareness of the problem situation and their own knowledge gaps, and raised their desire in subsequent learning (Kapur, 2016). The findings from Experiment 2 do not appear to support either the cognitive load theory or the productive failure hypothesis. One possibility could be that while biochemistry students had relatively higher prior knowledge, their knowledge did not overlap fully with the content covered in the instructional video. Thus, while these students had higher prior knowledge than introductory biology students, they may have still had low prior knowledge relative to the learning materials. If that is the case, the findings from Experiment 2 could be interpreted as providing some support for the cognitive load hypothesis.

In summary, our findings suggest there is not a straightforward relationship between students’ level of prior knowledge and the instructional sequences. This paper adds empirical evidence to the existing literature about instructional sequences, specifically on students’ prior knowledge and a challenging concept in undergraduate biology education research.

Growth mindset messages from instructors narrow equity gaps in introductory biology.
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Laci Gerhart-Barley (University of California Davis); Colin Harrison (Georgia Tech); John Hinz (Washington State University); Makita White (Washington State University); Lisa B Limeri (Texas Tech University)

Abstract:
Study Context: Traditional mindset research has explored how students’ beliefs about whether their intellectual abilities can improve (i.e., growth mindset) or are unchanging (i.e., fixed mindset) influences their motivation and academic outcomes (Dweck, 2000; Yeager et al., 2019). However, recent research on mindsets has shifted away from a deficit model (i.e., “fixing” the student’s belief system) towards an anti-deficit model, which focuses on the mindset culture that students navigate (Canning & Limeri, 2023). To this end, recent correlational and experimental laboratory studies revealed that when instructors communicate a growth mindset, students were more motivated, earned higher grades, and grades were more equitable across social groups (Canning et al., 2019; Muenks et al., 2020; Kroeper et al., 2022). This research suggests that instructor mindset beliefs may be an overlooked barrier and potential point of intervention for stigmatized students. Yet, little is known about how instructors can best communicate growth mindset beliefs to students and there is little experimental field evidence for specific strategies that instructors can implement in their classes to communicate
growth mindset messages.

We ground our research in mindset theory (Dweck 1999, Murphy & Dweck 2010) and research on “light-touch” or “wise” intervention strategies (Walton & Wilson 2018). We hypothesized that delivering growth mindset messages at a time when students may be questioning their ability or how to succeed in the course (i.e., first week of classes; directly after exams) would provide students with a pathway for subsequent improvements in their biology performance. The current research experimentally examines whether growth mindset (vs. control) instructor messages increase performance among Persons Excluded due to Ethnicity and/or Race (PEER) students in introductory biology courses.

In this study, we make three important advancements. First, we test low-effort strategies that instructors can use at scale to effectively communicate a growth mindset. Second, we conducted a large experiment in which students were randomized to condition within each course at the student level. This allowed us more power to determine causality than all other studies on this topic, which typically use different sections, instructors, or terms as control groups and allowed us to control instructor-level characteristics, such as their personality and teaching style. Third, our large sample included diverse institutions to increase generalizability and to specifically explore effects for PEER students.

Research Design: We recruited four introductory biology course instructors at three different institutions in the U.S. (1 designated as an Hispanic-Serving Institution (HSI) and an Asian American & Pacific Islander Serving Institution; 1 designated as an Emerging HSI; and 1 Primarily White Institution). Four instructors taught 7 course sections across two academic terms (Fall 2022 and Spring 2023). All students were randomly assigned to receive syllabi, emails, and course handouts containing either growth mindset or control messages. Students who consented to release their academic records were included in the final sample (consent rates ranged from 82-90% across institutions). The final sample included 3,397 students (28.7% PEER; 21.5% Hispanic, 4.1% Black, and 2.9% Native).

Analyses and Interpretations: We analyzed students’ grades in the course as a function of experimental condition. We found that the intervention improved course grades for PEERs, which was largely driven by an increase in their midterm exam grades. In the control condition, majority students significantly outperformed PEER students on the midterm exam, earning over half a letter grade higher (7.12% point difference), on average, F(1, 3384) = 82.85, p < .001. This is consistent with known opportunity gaps between majority students and PEERs in introductory STEM courses. However, in the instructor growth mindset condition, this opportunity gap in performance was reduced by 36.9% (4.49% point difference). That is, when the professor communicated a growth mindset message (vs. control) it significantly increased PEER students’ performance on the exam, F(1, 3384) = 5.10, p = .024, but did not increase majority students’ performance, F(1, 3384) = 1.36, p = .244.

Contribution: When instructors communicate a growth mindset, students are given a pathway for improvement and success. These messages suggest to students that their ability is not defined by previous performance, but with effort, improved strategies, and seeking-help, ability can improve over time. Our results provide a proof-of-concept that low-effort techniques (syllabi and email messages) are effective strategies that instructors can use to communicate growth mindset messages and reduce equity gaps in introductory biology courses.
From Fragments to Framework: Bridging Literature and Student Experience to Construct a Unified Theory of Race & Essentialism in Biology Education.

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Abstract:
STUDY CONTEXT:
Students’ beliefs and biases about race have ripple effects throughout society, and classrooms hold a key role in developing those beliefs (Donovan 2022). As such, teaching to reduce biases and convey accurate science is imperative. Students hold ideas of genetic essentialism (Morning 2009), the incorrect belief that racial groups are biological with genetic distinctions rather than being socially constructed (Andreychik & Gill 2015). Work has shown that classrooms can reinforce or deconstruct such beliefs, depending on teaching strategies employed (Donovan et al. 2020), but a unified theory to explain these phenomena is currently missing from the field. Such a theory describing students’ incorrect beliefs is needed, both to effectively guide instructional design in deconstructing those beliefs, and to facilitate additional research regarding students' beliefs about race (AERA et al. 2014). Therefore, we aim to develop a theory of genetic essentialism and test it in the context of introductory biology education.

The theoretical frameworks for this study are drawn from the many proposed belief components of essentialism (e.g. Haslam et al. 2000; Harden 2023). A major finding of this study is our unified conceptual framework, which we synthesize from engaging these existing fragments of theory then apply and test in biology classrooms. Our research questions are (1) how can racial beliefs about genetic essentialism be modeled as a cohesive theory, (2) how do introductory biology students justify their beliefs about race, and (3) how do these findings refine the theory we developed?

STUDY DESIGN:
The theory for this work was built by critically synthesizing theoretical frameworks spanning disciplines including philosophy, biology, and sociology. We also conducted semi-structured interviews with 18 undergraduate students in introductory biology courses. Using theoretical sampling and grounded theory methodologies (Charmaz 2014), we performed interviews in multiple rounds with iterations on the protocol to better probe students’ beliefs. We used qualitative content analysis (Hsieh and Shannon 2005) and reflexive thematic analysis (Braun & Clarke 2006, 2021) to analyze interview transcripts. Comparing students’ beliefs to our integrated theory and collected course materials allowed us to identify consistencies and differences.

ANALYSES & INTERPRETATIONS:
Within the 20 theoretical frameworks in our sample, we identified over 15 distinct theoretical belief components (constructs) of interest. After building several theoretical maps to describe the constructs’ relationships, we iteratively combined and revised to consensus, and an external evaluator confirmed conceptual clarity. For the interviews, our descriptions of student racial beliefs were constructed through iterative consensus coding and discussion, developing a codebook spanning racial understanding and biological concepts.
The study resulted in a conceptual framework of belief components with relationships and hierarchies that cohesively integrated every framework in our sample. Our final framework consists of two super-constructs, Entitativity and Natural Kinds, respectively illustrating how holding essentialist beliefs involves both believing that categories like race are (1) cohesive and meaningful, and (2) based in truths of the natural world. 11 additional beliefs are organized underneath these super-constructs in three layers of sub-components. The interviews highlighted how framework components bear out in students justifying their racial beliefs. Student drew on essentialist beliefs in a variety of ways, including direct biological bases for race as one participant justified disparities in sports: “Blacks, they’re engineered to be physical, like athletes…they just have the genes for it.” Further, students’ views were inconsistent depending on how directly their essentialist beliefs were activated, and some students conflated race with geographic origin, complicating how classrooms ought to define and address race. The ways students justified their beliefs largely supported the cohesive theory we built, and the application of our framework suggested some theory—like constructs pertaining to mixed-race identity—may be less salient.

CONTRIBUTION:
This study is the first to develop a unified theory of essentialism embedded in the context of biology courses, synthesizing numerous studies across decades of work in several disciplines. Our framework is supported and refined both by literature sources and student interviews, allowing the biology education field to apply essentialism theory to understand the nuanced racial beliefs students bring to the classroom. By highlighting incorrect racial beliefs that need to be confronted and providing examples of how students justify them, our work guides justice-oriented instructional design and enables further work in both research and teaching of wide interest to the biology community.

Session 4_C
What and How NEON Data are Used to Promote Ecological Literacy.

Josie Otto (Colorado State University)*

Abstract:
For nearly twenty years, the National Ecological Observatory Network (NEON) has been noted for its transformational potential in promoting ecological literacy in undergraduate classrooms (Balch et al., 2020). Since 2016, NEON scientists and university faculty have collaborated to create data-focused Open Education Resources (OERs) for use by STEM instructors (Nagy et al., 2021). The development and promotion of OERs coincided with calls for curricular reform in undergraduate ecology education (Ruhl et al., 2022). While various tools were becoming increasingly available, there were no clear or sanctioned guidelines as to what competencies of ecological literacy should be articulated in the classroom. To address this, in 2018 the Ecological Society of America developed the Four-Dimensional Ecology Education (4DEE) curricular framework of essential ecological educational guidelines. These dimensions include 21 elements that fall into the categories of Core Ecological Concepts (CEC), Ecology Practices (EP), Human-Environment Interactions (HEI), and Cross-Cutting Themes (CCT). Although it is widely acknowledged that NEON can be an effective tool for building ecological skills, to date, there are limited examples of how this resource can be applied to meet the goals of the 4DEE model in science classrooms. Furthermore, many of NEON’s data products are incomplete, making it challenging for instructors to integrate NEON data into their lessons or even create their own lessons using the open-access data. There are also a limited number of faculty with
data-science skills who can access and manipulate the data. The purpose of this study was twofold: 1) to conduct a synthesis and critical reflection of how NEON data are used in ecology classrooms, and 2) to determine how well the published lesson plans incorporated the concepts within the 4DEE framework. We conducted a systematic review of all published lesson plans and teaching modules that claimed to use NEON data. Within this review, we documented what and how NEON data were being used, what ecological principles and scientific practices were applied, what grade-level the lessons were designed for, and what learning objectives were used to quantify student achievement. Additionally, we evaluated the extent to which data gaps may inhibit students’ learning. To address our second research question, we conducted a deductive qualitative analysis of the alignment between activity learning objectives and the principal dimensions of the 4DEE framework. Our review resulted in 35 lesson plans of which 16 were adaptations of already published lessons. These adaptations were often modified to include more locally relevant data or were adjusted to fit different learning environments (i.e., in-person/hybrid/online or lecture/lab). Nearly 1/3 of all lessons did not actually use NEON data but instead followed a NEON sampling protocol, mentioned an interest in using the data when it became fully available, or were adapted such that data from other resources were used. A diversity of taxa was represented across the 35 lessons, including the use of data from angiosperms and gymnosperms, fungi, birds, small mammals, and insects. The focus of these datasets ranged from community structure and function to mutualistic networks to impacts of natural disturbances. All lesson plans incorporated quantitative reasoning and science inquiry skills, such as developing and testing hypotheses. Due to the data-driven nature of these lessons, all but one was developed for use in undergraduate classrooms. For the completeness of data, we found mixed results across sites in a variety of metrics that are core to NEON’s potential. While all the lessons had elements of EP (100%) and a majority featured components of CEC (69%) and CCT (77%), only 23% included aspects of HEI. These findings suggest that while the use of NEON for building quantitative ecological skills is well established, how this resource is used for teaching crucial human components of our ecological systems is underdeveloped. This study will present both an analysis and a set of recommendations for how this robust ecological data tool can be fully leveraged in the classroom to help students understand the complex interrelationship between humans and their environment. We intend to inform educators on how to better realize the potential of NEON in developing students’ comprehensive ecological literacy needed to solve society’s most pressing social-ecological problems.

Assessing the Biological Accuracy of Biomimicry Statements for General Biology Instruction: Perspectives from Biology Professionals and Undergraduates.

Dimitri Smirnoff (University of Minnesota)*; Anita Schuchardt (University of Minnesota); Gillian Roehrig (University of Minnesota); Emilie Snell-Rood (University of Minnesota)

Abstract:
Study Context
Biomimicry is the practice of understanding how organisms interact with their environment and solve problems they encounter so that we can apply these insights to inform how to solve analogous human problems (Bar Cohen, 2012; Baumeister et al., 2014). A key challenge in the teaching and practice of biomimicry is the incorporation of biological knowledge and concepts. To make biology more accessible, the biomimicry community developed statements (Baumeister et al. 2014; Biomimicry Institute, n.d.) that attempt to summarize how biology works using language that is both accessible and relevant to non-biologists. The claim that these statements distill the complexity of biology and make it accessible to a general audience raises the question: could these statements become a tool for general
biology education? Though an enticing proposition, the biological accuracy of these statements have not yet been systematically assessed. Moreover, some have expressed concern that they are not entirely biologically accurate (Lecointre et al. 2023) and may be inadvertently causing or reinforcing misconceptions about biology. Our research is the first to investigate whether and to what extent these biomimicry statements are biologically accurate and, thus, whether they are a potential tool for general biology instruction.

Study Design
Our first research question (RQ1) asks how do professional biologists perceive the biological accuracy of these biomimicry statements? Our second research question (RQ2) asks how do the perceptions of biology undergraduates of these biomimicry statements compare to those of professional biologists? To answer these questions, we surveyed biologists at differing career stages; respondents identified at least one professional area of experience, educational background and current career stage. A total of 58 statements were generated, including biomimicry statements and a set of statements generated by our research team to serve as a comparison group. Respondents were presented with 10 randomly selected statements and were asked to indicate their level of agreement regarding their biological accuracy using a six-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree”. Biological accuracy was defined as “whether this statement accurately represents what happens in the natural world”.

Analyses and Interpretations
Our research uncovers—for the first time—the biological accuracy of these biomimicry statements as perceived by biologists at various career stages. Answering RQ1, we found that biology professionals had a standard mean accuracy ranking of “somewhat agree” (4.42). We used one standard deviation (0.83) of the mean to determine which were perceived as most accurate (15 statements) or least accurate (11 statements). To the extent that professional biologists have the best basis for evaluating biological accuracy, these results indicate that not all biomimicry statements are biologically accurate.

Next, answering RQ2, we found that students had a higher standard mean accuracy ranking of “somewhat agree” (4.74). We used one standard deviation (0.57) of the mean to determine which were perceived as most accurate (9 statements) or least accurate (9 statements). We then compared perceptions of accuracy between biology professionals and undergraduates to determine where there was divergence. Biology undergraduates ranked 18 statements as more accurate than biology professionals, suggesting that, for these statements, the undergraduates were failing to notice biological inaccuracies perceived by professionals. Biology undergraduates ranked 5 statements as less accurate than biology professionals, suggesting that, for these statements, the undergraduates were failing to accept biological accuracies perceived by professionals.

Contribution
This is the first study to systematically evaluate the biological accuracy statements used in the practice and teaching of biomimicry. Our results confirm that not all statements used in biomimetics are perceived as accurate by the biology professionals sampled by our survey. Their perception may be because of how the statement is phrased or because of the concept embedded in the statement. Our results further reveal that biology undergraduates diverge in their perception of biological accuracy from biology professions, sometimes overestimating a statement’s biological accuracy and sometimes underestimating it. Since analysis of Likert-scale responses does not explain the reason behind a respondent’s level of agreement, our future work will analyze answers to open-ended questions asking respondents to explain their rating, which will illuminate whether a statement can be phrased differently or must be rejected.
outright. Once statements are evaluated for accuracy, they can be adopted to make biology more easily accessible and relevant to biology undergraduates.

**Analysis of STEM student perspectives on communicating about emerging and uncertain scientific issues.**

Nicole Kelp (Colorado State University)*; Abby Howk (Colorado State University); Rachel McMillan (Colorado State University)

Abstract:

Study context: Scientific is inherently uncertain in both conceptual and quantitative ways (1). Psychology and communication research explains how people respond to the ambiguity and potential anxiety caused by uncertainty (2). Uncertainty Reduction Theory focuses on how people seek information in order to reduce these negative aspects of uncertainty (3). Conversely, Uncertainty Management Theory acknowledges that individuals may choose to remain in a state of uncertainty rather than seek information to reduce it (4). The Theory of Motivated Information Management adds the importance of the trust and emotions in determining these decisions (5).

Study design: While there is extensive research regarding how communicating scientific uncertainty impacts different audiences (6,7), and there is research on how K-12 students consider scientific uncertainty (8–10), there is limited research on how undergraduate and graduate STEM students conceptualize and communicate about scientific uncertainty. Since STEM students may be asked to communicate about emerging scientific issues to their communities (11), it is important to understand how STEM students consider uncertainty communication so educators can better prepare them for these conversations.

In order to address this issue, we utilized Q methodology, which combines qualitative and quantitative approaches in order to cluster individual viewpoints around shared attitudes (12–14). We used Q methodology to assess STEM student viewpoints about communicating scientific uncertainty with diverse audiences. We used established Q methodological recommendations (13,15,16). The first step of Q methodology is creating the Q concourse, a list of possible perspectives on an issue. We developed the Q concourse by interviewing n=25 STEM students and scientists about their processes for uncertainty communication. We refined the Q concourse to 37 Q statements of the main concepts expressed by interviewees. We then recruited a diversity of STEM undergraduate and graduate students (n=14 so far) to sort these statements based on their agreement with the statements (the Q sort).

Analyses and interpretations: We utilized factor analysis using Q methodology software (ken-q analysis on github) to analyze student Q sort responses. Factor analysis suggested two factors for how students rated the statements, with Factor 1 suggesting intellectually-driven response to and communication of uncertainty (more in line with Uncertainty Reduction Theory) and Factor 2 suggesting emotion-driven responses (in line with Theory of Motivated Information Management). Students grouping into Factor 1 were more in agreement with statements that STEM students should be taught about uncertainty in science as inherent, that they should answer people’s questions about science and be direct about uncertainties with plain language and data, and that they leave their personal fears out of conversations about uncertain science. Conversely, students grouping into Factor 2 were more in agreement with statements that trust is the most important part of science communication, that they find uncertainty in science to be stressful or a deficiency in science, that people who spread misinformation might...
have valid reasons for doing so, and that scientists should learn from non-scientists’ life experiences.

Contribution: These data provide evidence on how undergraduate and graduate STEM students think and communicate about uncertain and emerging scientific issues. Uncertainty and trust in science are key components in science education and communication (17) and are thus valuable for science educators to address in the classroom. Our factor analyses revealed that students are considering scientific uncertainty from distinct perspectives and may benefit from targeted trainings depending on their degree of emotional connection with audiences during times of scientific uncertainty. Utilizing this Q sort could serve as a “diagnostic” tool to help educators adjust their teaching for different students or as a pre/post assessment to determine if and how students change their perspectives in response to training in scientific uncertainty and science communication.


Write and Review Like a Scientist: Tools for Improving Discipline-Specific Writing Skills.

Rachael Barry (UC Irvine)*

Abstract:
STUDY CONTEXT: The dissemination of scientific results through the publication of manuscripts in peer-reviewed journals is a cornerstone of modern biology research. In STEM education, scientific writing and science communications are listed as key competencies in Vision and Change (AAAS, 2010). Understanding publishing norms and how to write, review, and revise manuscripts within discipline norms can all be part of biology writing instruction at the undergraduate level. Though many biology degree programs feature some discipline-based writing education, providing opportunities for receiving high quality feedback is challenging in large enrollment courses. Our goal with this work is to provide new tools for student writing feedback that scale for medium to high enrollment courses. One commonly used strategy to deal with this scale problem is the use of student peer review; however, these peer reviews can be highly variable in quality. For example, many novice biology students find effective peer review challenging leading to pedagogical innovations targeting improving the student peer review process (e.g., Brigati and Swann, 2015). Writing, peer review, and revision cycles are one area where novices and experts may vary significantly their approaches based
on cognitive load theory (Miller, 1956; Sweller et al. 2019). As a result, we built new curricula that prompted students to provide reviews in a similar format to those done by experts reviewing for journals. Another recent area of interest is the use of generative artificial intelligence (AI) tools in the classroom particularly in the areas of automated grading and personalized teaching (Baidoo-Anu and Ansah, 2023). Here we present a two part project to educate students about scientific writing norms, engage them in the review process, and expand the types of review and revision opportunities available.

STUDY DESIGN: These tools were developed for upper level, project-based laboratory courses with medium to high enrollment (100 - 200 students per term). In these courses, students are expected to write manuscript-style final reports for an audience of their peers (upper level biology majors). In the first part of this project, we used backward design practices (McTighe, 2004) to create and implement a one-day instructional module on the topic of scientific publication and the peer review process (Kelly et al. 2014; Kumar, 2009). This included pre-lesson collaborative reading assignments, in class discussion, and a post-lesson assignment in which students peer review their classmates' manuscripts. In the second part of this project, we began testing the use of generative AI tools (e.g., ChatGPT) for providing feedback on the same student manuscripts.

ANALYSIS AND INTERPRETATIONS: To understand the effects of the new curricular module on student knowledge and attitudes about scientific writing and peer review, students were asked to complete a short survey in which they rated their level of understanding of the scientific publication process on a Likert scale before and after the lesson. The survey also solicited open ended responses about the relationship between the peer review process and trust in scientists. Summative assessment of student knowledge occurred when students were asked about this content on the final exam for the course. Student performance on publication and peer review content was compared to student performance on similar questions related to scientific writing topics that were not covered by the new module. Students were also asked to complete the Beliefs about Peer Feedback Questionnaire (BPFQ) (Huisman, 2020) based on their experiences. In this presentation, we will provide some initial impressions about the current capabilities of generative AI tools to provide feedback on student writing based on instructor-created rubrics. Current results with an example data set show that these tools can return feedback and grading information similar based on rubrics. This feedback is often consistent with traditional feedback and grading from graduate teaching assistants.

CONTRIBUTION: Learning the norms and expectations of scientific writing is important for building the scientific literacy of biology students and in building up professional communication skills. The new curriculum developed is intended to be adaptable to any STEM course that includes a formal manuscript as part of its curriculum. The pilot work with using generative AI as a source of student feedback suggests that this avenue may present another option besides student peer review to incorporate additional rounds of review and revision into the student writing process without significantly increasing the burden on instructors. These innovations have the potential to increase the scalability and quality of review and revision exercises and improve scientific writing education in medium to large biology courses.
Session 4_D

Discussion section structure: how does it impact students?

Liam O Mueller (UC San Diego)*; Claire Meaders (University of California, San Diego); Katherine Petrie (UC San Diego); Ella Tour (UCSD); Lisa M McDonnell (University of California San Diego); Ashley Juavinett (UC San Diego); Stanley M Lo (University of California San Diego)

Abstract:
Study context:
A large body of research has focused on how to support construction of knowledge in the classroom and foster student sense of belonging, resulting in recommendations for active learning and incorporation of learning assistants (LAs) (Freeman et al., 2014; Theobald et al., 2020; Wilton et al., 2019; Dewsbury & Brame, 2019). However, these recommendations can be difficult to implement in large-enrollment courses (Stains et al., 2018). One potential opportunity for students to experience group interaction with peers and LAs is in discussion sections. Discussion sections are scheduled course meetings led by a teaching assistant (TA) or LA. They are typically in smaller groups where students engage in discussions and problem solving, with goals of increasing access to instructional support and promoting student sense of belonging. Less attention has been paid to the impact of discussion sections on student experiences, and little is known about the relationships between discussion section size and modality and student interactions with teaching assistants, sense of belonging, and perceived learning.

Research questions:
In this study we aimed to: 1) characterize the designs of discussion sections across a multitude of biology undergraduate courses, 2) determine the relationship between discussion section modality and student engagement (attendance and interactions with the instructional team), student sense of belonging, and student perceived learning, and 3) identify features of discussion sections that students perceive as helpful or unhelpful for their learning.

Study design:
In our large R1 institution, students used to enroll in relatively small (up to 32-students), in-person discussion sections. This discussion section structure changed in Fall 2023, and in Biological Sciences students subsequently enrolled in either one large remote discussion section for all (hundreds) of enrolled students or larger in-person (up to 80-students) sections. This abrupt change set up a natural experiment, allowing us to assess the impact of section modality on student experiences. We collected survey responses from 5012 students enrolled in 20 different biology courses with discussion sections in spring and fall 2023. Students were asked closed-response questions regarding the modality of their sections, the instructional practices they engaged with in section (Meaders et al., 2018), sense of belonging (Clements et al., 2022), and perceived learning (Deslauriers et al., 2019; Gray & Diloreto, 2016), self-reported demographic questions, as well as an open-response question: “Please explain how discussion sections in this course are or are not helpful for your learning.” We are using both generalized linear models and permutation based simplex modeling to determine how student sense of belonging and student perceived learning are functions of student reported course structure, and inductive coding to analyze student responses to the open-ended question.

Analyses and interpretations: Students in remote discussion sections reported receiving significantly higher ($t=-17.25$, df = 4988, $p < 0.001$) amounts of lecture (M = 49% of time, SD
29%) compared to students in in-person sections (M = 32% of time, SD = 27). Fewer students in remote sections reported being comfortable asking questions (X2 = 146.7, N = 5007, p < .001). This was also demonstrated in the simplex analysis where students who were more likely to ask questions during discussion had discussion sections that they stated were more group work oriented (Barycentric Distance = 0.092, p < 0.001). Correspondingly, students in remote sections reported both students asking and answering significantly fewer questions (p < .001) compared to their peers enrolled in in-person sections. Interestingly, students who were more likely to report they felt a part of the course were also reporting that their discussion sections had significantly more group work (Barycentric Distance = 0.024, p = 0.012). Inductive thematic analysis of qualitative responses has identified several themes regarding aspects of discussion sections that students felt were helpful (e.g. increased access to support) or unhelpful (e.g. environments that were not conducive to learning). Overall trends in student responses will be presented, as well as relationships between student responses and discussion section attributes such as pedagogy, modality and size.

Contribution:
While discussion sections are common in higher education, their structure and relationships of structure and student experiences has been understudied. To our knowledge, this study is the first large-scale assessment of discussion section design and the first to use a pre- and post-design to identify the impacts of modality on student outcomes. Our findings offer insight into the variations of ways discussion sections are used in large biology programs and provide data to inform future discussion section design.

Overcoming Instructor Barriers to Using Culturally Responsive Teaching Practices.

Emily Rabung (The Ohio State University)*; Amy Kulesza (Center for Life Sciences Education); Ariel Rawson (The Ohio State University); Maria Miriti (The Ohio State University); Becky Mansfield (The Ohio State University)

Abstract:
Study Context: Despite the increasing recognition of the value of diverse scientists and a growing number of diversity-related initiatives, recruitment and retention of minoritized students is still low in ecology and environmental science (EE) fields (Beck et al., 2014; Taylor, 2014). While some solutions focus on what minoritized students are lacking (i.e. the “deficit model” foundational to pipeline strategies), we instead seek to address retention by attending to the cultural and social barriers to STEM participation such as those isolate and marginalize diverse students (Foor et al., 2007; McGee, 2016; Miriti, 2019). Breaking from traditional cultural norms and practices within the ecology curriculum to make cultural bridges to students has the potential to support a sense of ecological identity and sense of belonging among diverse students ultimately encouraging their retention in the field (Miriti, 2021). Introduced by Gloria Ladson-Billings (1995), culturally relevant pedagogy “addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate” (p. 469). Culturally Responsive and Culturally Sustaining are two related ideas that build out actionable ways to address the cultural needs of students (Gay, 2018; Paris and Alim, 2017). However, faculty professional development may be needed to see an increase in the use of culturally relevant pedagogies (Woods et al., 2023). We posit that by supporting instructors’ use of culturally responsive teaching (CRT) practices in introductory and intermediate courses, we will see an increase minoritized students’ sense of belonging and competence, eventually leading to increased student retention in EE fields.
Study/Research Design: In order to develop and assess inclusive CRT tools that are based on evidence-based pedagogical models to support the retention of underrepresented students, we started with an investigation of the challenges and barriers experienced by instructors in using these teaching practices. We used a needs assessment to answer our main research question: What training, information, and resources do EE instructors already have and what additional support do they need to include CRT practices in their classrooms? Specifically, we conducted semi-structured interviews with introductory biology and ecology course instructors asking about their knowledge of, and experience with, CRT pedagogy, as well as what they see as the barriers and opportunities for implementation (Brinkmann, 2020). We applied qualitative coding to transcripts of interviews to identify common themes about which practices were perceived as most difficult, what challenges needed overcome, and what resources would best support instructors.

Analyses and Interpretations: Multiple team members coded transcripts from a mutual codebook (i.e. set of categories used to described sections of text) and then met to arbitrate differences in interpretation. The coding process focused on instructors’ experiences with specific CRT practices, barriers to using CRT overall, and resources they felt would help them overcome those barriers. From that analysis, we present three main findings. 1) Instructors identified addressing power dynamics of science and incorporating student experiences into class as the two most difficult practices to implement. 2) The biggest barriers to implementation reported were a lack of knowledge and difficulty integrating CRT practices into large survey courses with hundreds of students and many learning outcomes. 3) Instructors expressed an interest in the combination of two interrelated resources: trainings that feature heavy peer discussion about applying CRT and occur at least yearly and a clearinghouse of examples and background information. Therefore, resources for instructors would likely be most effective at helping them overcome barriers if they: 1) helped instructors identify how narratives of power dynamics and specific student interests can be incorporated into the learning outcomes of introductory courses 2) demonstrated the application process through a hands-on workshop and additional examples of teaching 3) and filled gaps in background knowledge through the exchange of ideas with peers both in-person and through a repository.

Contribution: We address the call in the literature to design faculty professional development for incorporating culturally responsive pedagogy (Woods et al., 2023). Specifically, by investigating the instructor experience with CRT, we identify the types and characteristics of resources that would be most helpful to overcome barriers currently experienced, and make recommendations for support instructors use of CRT.

Breaking the opportunity barrier? Understanding the short-term effects of a light-touch intervention from TA reaching out using Regression Discontinuity (RD) design.

Shangmou Xu (University of Washington)∗; Elli J Theobald (University of Washington)

Abstract:

1. Study Context

Teaching assistants (TAs) play vital roles in undergraduate science, technology, engineering, and mathematics (STEM) instruction, especially in introductory-series courses. Past research has argued that a good TA practice can have a positive influence on students’ learning outcomes, such as self-efficacy (Stand and Roll, 2014), achievement (Wheeler, et al., 2017), or STEM retention (O’Neal et al., 2007). However, minoritized students disproportionately
benefit from TAs in the STEM classroom (Perlmutter et al., 2023). We provide two interpretations from the literature to conceptualize this inequity. First, as theorized by the opportunity hoarding theory (Riegle-Crumb, 2019; Tilly, 1997), advantaged students preserve resources and information of, for example, interaction with TA, as an effective way to maintain their advantages in the class. Second, as suggested by the identity-based motivation model (Solanki and Xu, 2018), minoritized students are less motivated to interact with TAs if TAs are not from minoritized groups.

2. Study Design

2.1 Intervention

To encourage more frequent interactions with TA, we implemented a light-touch TA reaching out intervention in an introductory-series biology course. In this study, we examine the effectiveness of this intervention on students’ learning outcomes. Specifically, we aim to understand:

1. whether enforcing contact with TAs have a positive effect on short-term learning outcomes, and
2. whether minoritized students experience a similar positive effect as their majoritized peers.

Participants were students enrolled in one of the four introductory biology sections throughout the 2022-2023 academic year (n=3062). In each section, the instructor asked TAs to reach out to students who were falling behind during the first half of the quarter. Critical to this analysis, students below 71.5 points got the intervention and students above this threshold didn’t. Students who got the intervention received an email from their TA, encouraging them to interact with TAs. This light-touch intervention served as a reminder for under-performing students who were likely reluctant to interact with TAs. To observe the effect of this intervention, we collected students’ exam scores on the following exam.

2.2 Regression Discontinuity Design

Regression Discontinuity (RD) design explores the local effects of an intervention in the case where the criterion is clearly set. In this study, we used 71.5 points as a clear cutoff for TA reaching out, making this analysis well-aligned with the RD design. To understand the effect of reaching out, we fitted the following multilevel model under RD framework,

\[ \text{Exami} = b_0 + b_1 \text{Reachouti} + b_2 \text{CenterGradei} + e_i + r_j \]

where Reachouti is a binary indicator of reaching out. The estimation of \( b_1 \) indicates the effect of TA reaching out. We performed both bandwidth selection and model selection techniques to decide the optimal bandwidth, model specifications, and the structure of random effects.

To achieve the second research goal, we further added an interaction term between reaching out status and student group identities (e.g., first gen vs. continuous gen) to test whether reaching out disproportionately benefited minoritized students.

3. Analyses and Interpretations

As a key assumption of RD, there should be nothing appreciably different between students who were just below and above the threshold, other than their intervention status. Thus, the estimation from RD is sensitive to bandwidth, the distance from the cutoff in either direction. In this analysis, we narrowed our bandwidth to +/-15 points. Model estimations show a marginally significant main effect of TA reaching out, with an increase of 3.31 points (out of 100 points) in the next exam score among students who received reaching out, compared to other students (b=3.31, SE=1.84, p<.1).

Additionally, we added a set of interaction terms between reaching out status and various
group identities separately. Model estimation results show that neither first generation status nor URM are significantly related to the outcome, indicating that, in general, minoritized students benefit from the TA reaching out to a similar extent as majoritized students.

4. Contribution
Benefits of frequent interactions with TAs in undergraduate STEM courses have been reported in many studies (Eagan et al., 2013). To resonate with prior studies, in this analysis, we demonstrate the marginally significant yet meaningful effectiveness of a light-touch intervention designed to enforce contact with TAs for under-performing students. Empirically, this study contributes to the existing literature regarding the importance of interaction with TAs. Practically, this study suggests that instructors and departments may explore various ways to facilitate students to interact with TAs.

Development, validation, and application of a scale to measure students’ planned behavior in inclusive science communication.

Delaney Worthington (Colorado State University)*; Hannah Gilliard (Colorado State University); Barb Graham (Colorado State University); Nicole Kelp (Colorado State University)

Abstract:
More science educators are seeking to add science communication to undergraduate curricula (1). However, many published science communication curricula for STEM students do not focus on inclusive approaches to science communication (2, 3), even though inclusive science communication (ISC) is shown to be more effective (4) as well as empower students from marginalized backgrounds (5). There are also not many validated methods to evaluate the efficacy of ISC training (3). Existing validated scales for assessing students’ science communication attitudes and skills exist (6, 7) but these focus on specific science communication skills like oral presentations and do not explicitly focus on ISC approaches. To address this gap, in this study we aimed to create and validate a new scale to assess student ISC behaviors as well as demonstrate use of this scale to assess a variety of ISC trainings for students.

We created the Planned Behavior in Inclusive Science Communication (PB-ISC) Scale by building upon theories and epistemology of science communication research and science education research and rooted in concepts of the Theory of Planned Behavior (8, 9). The scale is designed to measure how undergraduate STEM students’ attitudes, norms, and self-efficacy influence their behavioral intents and behaviors in inclusive science communication. We utilized data collection from hundreds of diverse undergraduate STEM students at a large land-grant university for quantitative (exploratory factor analysis, EFA and confirmatory factor analysis, CFA) and qualitative (cognitive interviews) analyses to validate this multifactorial scale using established methods in the field (10).

To demonstrate how the PB-ISC can be an effective tool for measuring the impacts of ISC trainings, we utilized the PB-ISC to evaluate different types of ISC trainings. We used the PB-ISC to assess student growth in response to an ISC workshop that we have previously shown to increase student science identity and self-efficacy (5). This training increased all factors in the PB-ISC. We also utilized the PB-ISC to evaluate a modified version of the CREATE method (11) for reading primary scientific literature (PSL). Engaging with PSL helps students grow in science confidence & procedural knowledge, data analysis & critical thinking skills, and interest in science (12). In undergraduate life science and biomedical engineering courses we utilized the CREATE method – Consider, Read, Elucidate the hypothesis, Analyze the data,
and Think of the next Experiment – but modified it for students to Think of other Expertise and Experiences: that is, to consider what people of diverse disciplines and identities should be consulted for a scientific discovery to be utilized to solve a socioscientific issue (SSI). Socioscientific issues are valuable for students to consider (13,14), and this links reading PSL to SSIs. We used the PB-ISC to assess student growth in response to this inclusive CREATE (i-CREATE) method. We found that some PB-ISC factors increased significantly after students received the iCREATE training. This suggests a dually beneficial approach – students can glean the impacts of reading the PSL and considering SSIs as well as the impacts of ISC training within one class session, allowing efficiency and efficacy within the undergraduate STEM curriculum.

Overall, this study shows that the PB-ISC can be used by biology education researchers and practitioners focusing on inclusive approaches to science communication by helping them to set goals for incorporating ISC training and to evaluate the efficacy of existing trainings. Additionally, this study highlights the benefit of the iCREATE method as a novel form of ISC training.

References:

Preparing Graduate Teaching Assistants to use Equitable Teaching Practices: A Study at two Minority Serving Institutions.

Laurel M Hartley (Cu Denver)*; Carson Hedberg (University of New Mexico); Paul Le (University of Colorado Denver); Jennifer Pollar (University of New Mexico); Fayelynn Scheideman (University of Colorado Denver); Stephanie Spong (University of New Mexico); Oona Takano (University of New Mexico); Jasmine Vidrio (University of Colorado Denver); Satya Witt (University of New Mexico)

Abstract:
Study Context: At research universities in the United States, many undergraduate introductory and gateway small enrollment courses in biology (e.g., laboratories, recitations) are taught by Graduate Student Teaching Assistants (GTAs) (Sundberg et al., 2005). Research demonstrates that while training for GTAs increases their self-efficacy toward teaching, this training is often inconsistent or non-existent and rarely focuses on inclusive teaching (DeChenne et al., 2012; Golde & Dore, 2001; Prieto & Meyers, 1999). Teaching itself is often undervalued or considered “secondary” to research, despite evidence that engagement with
teaching can support research excellence and does not necessarily delay graduate student progress (Feldon et al., 2011, Shortlidge & Eddy, 2018). Graduate students pick up on these cues from their departments and professors, expressing limited agency to deviate from accepted institutional norms in their teaching roles, and under-appreciation of efforts they put into teaching (Shultz et al., 2019; Goodwin et al., 2021). This highlights the importance of intervening with graduate students at the outset of their careers to improve teaching to better support underrepresented students in STEM, and the need for greater student voice and agency in the process (Boyerr, 1990).

The goal of developing an equity focused GTA training is to empower GTAs to improve the student experience of biology courses. Our conceptual model includes a “foundation” and three “pillars” that are all required to uphold and support an improved student experience. The “foundation” includes understanding students at our universities and their unique lived experiences and goals. This foundation is necessary to support three “pillars” that then promote an improved student experience: (1) equitable teaching practices (ETPs) to improve the student experience, (2) student feedback, and (3) a community of practice (CoP) to support GTA engagement and professional development.

Study Design: We designed, delivered, and assessed a semester long GTA Community of Practice about equitable teaching practices (ETPs) (e.g., normalizing use of academic resources, incorporating diverse examples) at two public minority serving institutions. Activities of the CoP were developed by GTAs and faculty at the universities in partnership with national scholars in equity work and a US higher education association. Activities were modeled from faculty focused training that was co-developed by six universities and is now being used at an additional 30 universities. ETPs are based on research on growth mindset, social belonging, and identity safety (Dweck, 2006; Murphy & Destin, 2016; Murdock-Perriera et al., 2019).

We surveyed GTAs (N = 45) at the beginning and end of the CoP to assess their beliefs and experiences along six dimensions of GTA experience, including GTA’s self-reported beliefs about undergraduate student’s ability to learn and grow, feelings about their own self-efficacy as educators, familiarity and comfort with employing ETPs, perceived departmental and instructor support and training for GTAs to use ETPs, use of ETPs, and interest in engaging in opportunities to learn more about ETPs. We also collected artifacts to explore the GTA implementation of ETPs.

Analyses and Interpretations: We will present findings from both the pre-post survey and the artifact analysis. Survey findings demonstrate that program participation had a positive and meaningful impact on GTA familiarity (p<.001) and comfort (p<.001) with utilizing ETPs in their courses, leading to increases in ETP use by 25%-61% across the 17 ETPs introduced in the CoP. Across participating campuses, there were significant impacts on GTA’s mindset beliefs about the relationship between effort and success (p<.05); and GTA interest in continuing to participate in professional development opportunities that will enhance their ability to utilize ETPs in their teaching (p<.01). GTA’s across both campuses overwhelmingly reported that the training program provided appropriate training to learn about and effectively implement ETPs (a 104 % increase from beginning of term to end of term).

We categorized the GTA’s artifacts and explored how they were related to the disciplinary context of biology. The categories of the artifacts included feedback framing statements, belonging statements, growth mindset statements, and reflections about identity safety. Biology specific contexts in the artifacts included issues around biological sex, identifying as a biologist, and the relationship between scientific content and students’ cultural background and...
identities.

Contribution: This work supports that training GTAs to use ETPs increases GTA comfort with and use of ETPs, changes GTA mindset beliefs, and motivates GTAs to participate in further equity training. Materials developed by the project will be publicly available through our partner US higher education association.
Concurrent Short Talks – Session 5

Session 5_A


Yoon Ha Choi (Digital Promise); Elli Theobold (University of Washington); Sarah L Eddy (University of Minnesota)*

Abstract:
Study Context: Active learning, on average, increases student performance. Yet, there is also large variation in the effectiveness of these implementations. A consistent goal of active learning is moving students towards becoming active constructors of their knowledge. This emphasis means student engagement is of central importance. Thus, variation in student engagement could help explain variation in outcomes from active learning. In this study, we explore four aspects of course social & cultural environments & their impact on student engagement to identify leverage points that instructors can employ to encourage engagement in active learning.

We use Pekrun's control-value theory of academic emotions (CVT) to connect features of the course environment to student engagement. CVT posits that emotions experienced while engaging in course activities influence student academic-related behaviors. Appraisals of the course environment influence these emotions. CVT identifies two key appraisals: control & value. Control is a student’s perception that they can influence their achievement actions and outcomes. Value is a student’s perception of the importance of achieving course outcomes. When both are high students experience positive emotions & when one or the other is low they experience negative emotions. The final element of CVT are features of the course environment. Student perceptions of these provide information about their ability to control their success & the value of the tasks they are asked to do.

We focused on features of the course environment that instructors can use to influence student engagement through control, value, & academic emotions. We chose four that have been related to student emotions in the literature & we hypothesize relate to control and value. Goal structure is a student’s perception of the goals for learning that are established in the course. Goal structure could emphasize a mastery approach (focused on developing competence) and/or a performance approach (focused on looking competent). Relevance is a students’ sense of the importance of the course content and skills to them. We focus on relevance for helping others as prosocial goals are highly motivating to students. Instructor trust indicates the degree to which students perceive their instructor to be benevolent, reliable, competent, & honest. Course competition is the degree of interpersonal competition perceived.

Study/Research Design. Our research question was: How do features of the course environment (goal structure, instructor trust, relevance, & competition) relate to students’ appraisals of control & value, academic emotions, & through these, engagement in active learning courses?

We surveyed students in 13 introductory STEM courses. These courses were chosen because the instructors had either published on the effectiveness of their use of active learning or were recommended as using a similar approach by a colleague who had. Across these courses, 1,885
students responded to the survey. For the survey, we adapted existing measures of goal structure, relevance, instructor trust, competition, control, value, 7 academic emotions (surprised, curious, excited, confused, anxious, frustrated, & bored), & engagement.

Each construct was evaluated for validity through expert feedback & confirmatory factor analyses. We then ran a structural equation model that mapped how features of the course environment influenced control, value and academic emotions & how, in turn, control, value and academic emotions influenced engagement. Satisfactory fit of model was met (CFI=0.92, RMSEA=0.04; SRMR=0.05).

Analyses and interpretations: Engagement was positively related to control & value as well as the emotion of curiosity. Engagement was negatively related to the emotion of boredom. Importantly, features of the course environment influenced these four variables. All features influenced control: goal structure, relevance, & instructor trust increased it, while competition decreased it. All features expect competition were related positively to value. Goal structure, relevance, & instructor trust all reduced boredom, while competition increased it. Goal structure, relevance, & instructor trust also increased excitement. To understand the overall influence of features of the environment on engagement we calculated the total effects of each. Relevance had the largest positive total effect on engagement (standardize coefficient: 0.26). Mastery (0.15) and Instructor Trust (0.13) also had positive overall effects. Competition had a small but significant negative impact effect (-0.04).

Contribution: Overall, our study suggests that the way instructors structure the social & cultural environment in active learning courses can impact engagement. Building positive student-teacher relationships, reducing course competition, emphasizing mastery & the relevance of the course to students can all increase engagement in course activities.

Perceptions of interdisciplinary critical thinking among biology and physics undergraduates.

Ashley B Heim (Cornell University)*; Michelle Smith (Cornell University); Natasha Holmes (Cornell University); Georgia Lawrence (Cornell University); Riya Agarwal (Cornell University)

Abstract:
Study Context: There is a growing need for more effective interdisciplinary science instruction across undergraduate degree programs, including those in biology and physics (AAAS, 2010; AAMC–HHMI, 2009). In fact, students majoring in life sciences represent one of the largest demographics enrolled in physics, at least among science majors (Hoskinson et al., 2014). In addition to improving students' conceptual understanding, interest, and attitudes towards learning, interdisciplinary learning objectives can also develop students' critical thinking skills and allow them to make meaningful and relevant connections between diverse topics (Gouvea et al., 2013; Geller et al., 2014; Crouch and Heller, 2014). We adopted Gouveau et al.'s (2013) interdisciplinary framework to guide our research process; though not specific to critical thinking, this framework describes three levels of interdisciplinary student learning between biology and physics.

Research Design: This study focused on one primary research question: How does students’ perceived importance of biology and physics relate to their ideas about interdisciplinary critical thinking? Using a phenomenological approach (Creswell, 2013, we conducted semi-structured think-aloud interviews with biology majors (n=17) and physics majors (n=11) at a large research university, asking students to respond to questions focused on critical thinking and perceived
importance of both biology and physics. These questions included: (1) How would you define critical thinking? What does critical thinking look like in biology / physics?; (2) Why is biology / physics important in your life?; and (3) Do you think physics is necessary for understanding biology? Do you think biology is necessary for understanding physics? Why?

Analyses and Interpretation: We conducted thematic analysis to inductively code interview responses into emergent themes (Creswell, 2013), which were used to develop a rich description of the phenomenon (i.e., perceived importance of biology, physics, and interdisciplinary critical thinking among participating students). We found that biology and physics students provided similar definitions of critical thinking in the sciences and had overlapping reasons for why biology and physics were important in their personal lives. However, most students only reported on the importance of their own major (biology or physics) for their career, rather than discussing the importance of both. Additionally, most students stated that either (1) physics is necessary for understanding biology, but biology is not needed for understanding physics, or (2) neither biology nor physics is needed to understand the other, a phenomenon that could at least partially be explained by students’ discussion of a scientific hierarchy (i.e., math is needed to understand physics, which is needed to understand chemistry and subsequently, biology). Thus, it seems that while students recognize interdisciplinary importance in their personal lives, they find it challenging to foster meaningful connections between biology and physics in academic contexts. This conclusion is further supported by the identification of all three levels of interdisciplinary connection described in Gouvea et al.’s (2013) framework across students’ interview responses.

Contribution: Our findings suggest that students could benefit from more explicit connections and aligned learning goals across their biology and physics courses, and more exposure to interdisciplinary thinking in general. Emergent themes from students’ interview responses further support the need to transform or develop introductory physics courses specifically for life science majors (Meredith & Redish, 2013; Redish et al., 2014). The literature tells us a more integrated curriculum for life sciences majors across biology and physics courses can lead to more effective training of students in their use of technology, methodology, statistics, and modeling based in the physical sciences (Geller et al., 2014). Thus, by facilitating students’ abilities to make meaningful connections between their biology and physics courses, we as instructors and curriculum developers could help foster interdisciplinary learning, critical thinking, and a more integrated community of scientists at our institutions.

The Value of Support: STEM Intervention Programs Impact Student Persistence and Belonging.

Erin E Shortlidge (Portland State University)*; MacKenzie J. Gray (Portland State University); Suzanne Estes (Portland State University); Emma C Goodwin (Arizona State University)

Abstract:
Context: The attrition rate for students intending to earn STEM degrees is unswervingly high (Olson and Riordan 2012). In response to calls to strengthen and broaden representation in STEM, federal and non-governmental agencies invest in a diverse STEM future by funding STEM Intervention Programs (SIPs) for undergraduates (George et al. 2018). SIPs can provide support to students to increase retention and often recruit students who are historically marginalized in STEM as they provide a combination of key supports. This work leverages existing theory to investigate how SIP involvement influences student perceptions of psychosocial factors and experiences thought to lead to persistence in a STEM major (e.g., integration, science identity, sense of belonging (Tinto 1997; Estrada et al., 2016; Strayhorn 2018)). We also identify if student characteristics such as age and race/ethnicity play a role in how students experience persistence.
factors, and assesses if participation in a SIP leads to higher rates of persistence and graduation in a STEM pathway.

Research Design: Here we used a mixed-methods approach to study how SIPs and STEM student characteristics impact their experiences and persistence at one institution with a non-traditional population and multiple SIPs. We asked three research questions: 1) How does participation in a SIP affect factors related to student persistence at the university and in science? 2) How do student characteristics affect factors related to student persistence at the university and in science? 3) How does participation in a SIP affect students’ progression towards graduation? STEM Students were surveyed at one time point at the end of the academic year, followed by focus groups with a subset of survey participants, and graduation/persistence status checked 2.5 years post-survey.

Analysis and Results:
Specifically, we studied: sense of belonging, scientific self-efficacy, community values, scientific identity, and STEM involvement in a representative population of STEM students supported by a SIP (n=104) or not supported by a SIP (n=555) at one institution. We established that the surveys used (Bollen & Hoyle 1990; Estrada et al., 2018; Knekta et al., 2020) collected valid data in our STEM student population through confirmatory factor analyses (n = 633) which indicated acceptable fit statistics (Hancock et al., 2010). The graduation status of students was tracked longitudinally. We controlled for prior academic performance between SIP and non-SIP students and used linear and logistic regression to analyze latent survey constructs as well as retention in STEM.

Quantitatively, SIP students reported significantly higher science identity, belonging to a subcommunity, and were more involved in STEM-related activities than counterparts unsupported by SIPs (all p<0.05). Differences in measured factors also correlated with race/ethnicity, generation status, and age. SIP students were more likely to persist and/or have graduated in STEM than non-SIP students (p=0.03).

In total, 8 focus groups (n = 51 participants) were conducted following the survey administration with both SIP (n = 4) and non-SIP (n = 4) groups in effort to gain an understanding of the student experiences that were measured in the surveys. Three focus groups were iteratively coded to consensus using deductive content analysis by three coders to establish a final codebook. The codebook was then used by one researcher to finalize coding, checking with the research team with any concerns or questions. Focus groups revealed insights into the different experiences of SIP and non-SIP students as well as the measured psychosocial survey constructs. We gained nuanced insight into the student experiences that lead to the development of a science identity and a sense of belonging among a STEM community at our university.

Conclusions: We provide evidence that within one underserved student population at an urban university, SIPs can significantly influence STEM student experiences. A disparity between SIP and non-SIP students was revealed both quantitatively and qualitatively. Not only do SIP students express higher affiliation with psychosocial factors believed to lead to persistence, but they also persist at higher rates. SIPs provide and/or facilitate impactful support, and students without intentional support may be left behind. We hope this work convinces institutions to consider expanding access to SIP-like supports, such that more students benefit.
Examining the Exclusionary and Affirming Peer Interactions of Racially Minoritized Students in Active Learning Science Classrooms.

Hannah Nichols* (University of Georgia); Jordan Roberts (University of Georgia); Renette-Kaire Fopa Tchocksi (University of Georgia); Matthew Turnipseed (University of Georgia); Chase Anderson (University of Georgia); Tatiane Russo-Tait (University of Georgia)

Abstract:
STUDY CONTEXT: Studies on the interpersonal experiences of underrepresented, racially minoritized (URM; McGee, 2021) students in STEM higher education show that racialized exclusion occurs in most spaces in predominantly white institutions (PWIs). URM students contend with microaggressions, stereotyping, and discrimination while also pursuing their academic goals (NASEM, 2023). They also find counterspaces (Ong et al., 2017) where they engage in interactions that affirm, validate, and build community (Rolón-Dow & Davison, 2021). Active learning (AL) classrooms are often claimed to be another space where “equity gaps” can be addressed (Handlesman et al., 2022) though studies suggest that URM students also experience exclusion there (Stanton et al., 2022). As AL becomes institutionalized through "color-blind" approaches, students of color are further at risk of being harmed in their educational experiences. Thus, it is imperative to systematically characterize the experiences of racially minoritized students during peer interactions in active learning (AL) college science classrooms. Situated in Critical Race Theory (Solórzano et al., 2000), this study uses racial microaggressions (exchanges that disparage others based on race; Solórzano et al., 2000) and microaffirmations (cues that affirm/acknowledge racialized realities and resist racism; Rolón-Dow & Davison, 2021) as analytical lenses. RESEARCH

DESIGN: The research question guiding this study is: What are the exclusionary and affirming peer interactions of racially minoritized students in AL science classrooms at a PWI? Semi-structured interviews were conducted by Black and Latiné researchers with Black and Latiné student participants in a PWI in the Southern US. Data was analyzed via Template Thematic Analysis (Brooks et al, 2018). Iterative coding included deductive and inductive phases, themes were collaboratively developed and refined, and disagreements were resolved until consensus was reached. For trustworthiness member-checking was conducted. Positionality. We collectively identify as Scholars of Color who engage in this work in solidarity to contribute knowledge and practices that lead to equitable outcomes for URM students.

ANALYSIS/INTERPRETATION: Themes for negative interactions included Invisible, Hypervisible, Dehumanized, White Stereotype Threat, and White Male Culture. Due to space, select examples are shared. In the Invisible theme, Black and Latiné women reported their ideas being dismissed and ignored by white and male peers, which rendered them invisible. Lucy, a Latiné woman shared: "This happens to me a lot as a girl and a minority… whenever I'm working in collaborative spaces with a male peer, I'm disregarded or talked down to and that it is generally frustrating and upsetting and it makes me feel pretty stupid." Tasha, a Black woman, shared how she is literally deemed invisible by white peers during think-pair-shares: "I feel like because I'm a Black, people are less likely to turn and talk to me. They talk to each other around me, even once when I was like, in the middle." Black men on the other hand, felt Hypervisible, as James shares "I feel being the only Black male plays a major role in my interaction with peers. They see me and be a little like, intimidated or just be hesitant to come up to me". In White Stereotype Threat, participants shared a sense that white peers were afraid of talking with them. Julie, a Latiné woman shared "When I am working with a group of white people, and if there's another minority in the group, [white people] don't know how to handle that... They just don't talk and contribute!" Themes for affirming experiences included: Authenticity, Community, and Resistance. Of note, affirming...
experiences were almost always related to interactions with other racially minoritized students in AL classrooms. In the Community theme Ashley shared: One of my best friends, I met her in organic chemistry [AL class]... and we’ve taken every single class with each other since, and I feel like that's really helped just affirm, okay, I have another Black girl doing the same thing as me and we’re going through this together and it's hard, but we can conquer it.” Finally, almost all participants recognized the benefits of active learning and would not want to go back to lecture-only course formats. Instead, they shared how instructors could work to improve group dynamics, including how to select group members, enforcing inclusionary policies related to interactions in the classroom, and educating peers from dominant backgrounds on cross-cultural interactions and deficit assumptions of people of color.

CONTRIBUTION: This study advances our understanding of the tensions and possibilities of peer interactions in AL college science classrooms for URM students at a PWI. These findings can inform the design of active learning classroom structures and instructional practices that attend to racial equity in this learning environments.

Session 5_B

Testing three interventions to mitigate test anxiety and improve performance and retention in Norwegian STEM higher education.

Ruben Thormodsæter (University of Bergen); Sehoya Cotner (University of Minnesota)*

Abstract:
Study Context: Globally, we are not training enough scientists and mathematicians to meet pressing societal needs, patterns echoed in Norwegian higher education. For example, in the Faculty of Mathematics and Natural Sciences at the University of Bergen, attrition between years one and two of the bachelor program exceeds 30%. Test anxiety (TA) is one of the most common affective barriers for students (Cassady 2002), impacting who succeeds and persists in higher education. Given that there is documented variability in the individual experience of test anxiety (Chapell 2005), and that test anxiety has been demonstrated, in numerous studies, to negatively impact performance (von der Embse 2017), there is likely to be variability in how test anxiety impairs our assessment of our students. Further, there is evidence from the US (Ballen 2017) and Norway (Cotner 2020) that test anxiety can exacerbate inequities, possibly explaining some of the biased performance and retention gaps that have been documented in STEM fields.

Fortunately, there is compelling evidence that we can help students mitigate the impacts of TA (Hembree 1998, Zeidner 2007). With many of these actions, however, there have been few replication studies that allow us to contextualize the variable contexts in which a given pedagogical choice may benefit students. Here we present findings from three different interventions, in four different introductory-level courses at two Norwegian universities, where students are predominantly graded on a single, high-stakes test at the end of the semester.

Our primary motivating question was “which, if any, of three evidence-based test-anxiety interventions will be effective in lowering test anxiety and/or improving performance in our sample of Norwegian STEM students?”

Study/Research Design: Specifically, we tested (a) the implementation of Team-Based Learning (TBL, Michaelsen and Sweet 2004), hypothesizing that the readiness assurance tests that are a signature of TBL would lower test
anxiety through exam practice and teamwork
(b) a cognitive reappraisal exercise, in which students are led to see feelings of arousal (like test anxiety) as potentially beneficial (Jamiesen 2010)
(c) converting from high-stakes to low-stakes testing, in which no single metric is responsible for over 25% of a student’s final grade (Cotner and Ballen 2017), lowers test anxiety and improves performance.

At the University of Bergen, we tested one large (n>400) introductory math course in which TBL was implemented; one large (n>100) introductory biology course with TBL; and one large (n>100) introductory geoscience course. At the University of Agder, we tested one large (n>400) introductory math course that changed from a single high-stakes exam to multiple low-stakes exams. In all four courses, students were randomly assigned to either an experimental or a control group. The experimental group received the cognitive reappraisal intervention, and the control group received a placebo (Jamiesen 2010).

We collected demographic and performance data and, via survey, information on test anxiety three times during the semester. On a final survey, we collected information on intent to remain in STEM. We measured test anxiety as a construct of four items from the MSLQ (Pintrich 1991). We then tested for correlations between test anxiety and performance, and between test anxiety and intent to remain in STEM. We used a linear mixed effects model (lmer) to test the impact of the three interventions. Because high school grades are likely to predict university performance, we used average high school grade as a control for generalized incoming potential. We used the following model: lmer(Grade ~ lowStakes + TBL + reappraisal + (1|highschool_grade)).

Analyses and interpretations: We found that test anxiety is inversely and significantly correlated with grade (p<0.001) and intent to remain in STEM (p<0.01). We also found that of the three interventions, only the shift to low-stakes testing had a significant impact on grades (estimate 0.65, SE 0.23, p<0.005). In concrete terms, the failure rate in the low-stakes math class went from a historic range of 25-45% to 12%. Further, only in this course did we see test anxiety go down (estimate -0.44, SE 0.18, p<0.01) across the three measurement periods. We did not see any variability in impacts due to student characteristics such as gender or generation in college. These findings underscore the importance of low-stakes testing in STEM higher education.

Contribution: Our findings contribute to our understanding of test anxiety as a potential culprit in performance and retention in STEM fields, and further contextualize the impact of test anxiety interventions by studying them in a Scandinavian setting—one with, on average, much greater emphasis on summative exams. These findings have clear implications for curriculum design and assessment choices.

Using a QuantCrit approach to develop and collect evidence of validity for a measure of Community Cultural Wealth.

Rosario A Marroquin-Flores (Texas Tech University)*; Rose Marie Tijerina (Texas Tech University); Mason N Tedeschi (Texas Tech University); Sofia Banjara (Texas Tech University); Redmon Warmsley (Texas Tech University); Luke McFather (Texas Tech University); Zianna Casas (Texas Tech University); Lisa B Limeri (Texas Tech University)

Abstract:
Study Context: Students from minoritized identities are underrepresented in science, technology, engineering, and math (STEM) (Espinosa et al., 2019). Attempts to address disparate outcomes between minoritized students and those from the cultural majority often involve providing students
with cultural capital, the accumulation of skills valued by the cultural majority. However, this approach represents a deficit perspective, suggesting that minoritized students lack the skills they need to be successful but can improve by adopting normative values and practices (Ladson-Billings, 2006; Yosso, 2005). Community Cultural Wealth (CCW) is a framework that focuses on the cultural strengths that minoritized students develop in response to oppressive systems and which can be applied to educational contexts (Yosso, 2005). CCW has primarily been studied using qualitative methods, which can be time-intensive and often only capture the experiences of a small subset of students (Denton et al., 2020). A quantitative measure of CCW could be used to capture the strengths of student cohorts, expand CCW theory, and promote CCW as a framework for understanding college readiness. However, there is currently no measure of CCW that captures all forms of CCW capital (Braun et al., 2017; Hiramori et al., 2021; Sablan, 2019). In this research, we apply insights from critical theories to develop and collect evidence of validity for a comprehensive measure of CCW for use with STEM undergraduates.

Study Design: Critical Race Theory (CRT) scholars often critique the use of quantitative data, which have the potential to reinforce racist views and practices (Garcia et al., 2018; Pérez Huber & Solorzano, 2015). QuantCrit is a methodological framework that uses insights from CRT to inform quantitative research practices (Garcia et al., 2018). In alignment with best practices, we have applied a QuantCrit approach to measurement development (AERA, APA, and NCME, 2014; Castillo & Gilborn, 2022). Each member of our research team reviewed CCW literature, reflected upon and discussed our beliefs and experiences, and drafted items to capture our unique strengths. We also incorporated items from prior work (Hiramori et al., 2021; Sablan, 2019). We then collected evidence of validity based on response process, evidence that students interpret items as intended, using hour-long cognitive interviews (Desimone & Le Floch, 2004). We recruited minoritized students identifying with both visible and invisible forms of diversity using a screening survey where students could self-disclose identities and experiences. We selected participants whose knowledge could help us address specific questions related to item responses, and those with experiences that differed from members of the research team. Participant responses were used to revise items in the measure.

Analyses and Interpretations: Through an iterative process of discussion and reflection, we found that CCW was manifesting within our experiences as intersections between forms of CCW capital. For example, the development of resistant capital, the ability to push back against oppressive systems, was often a product of familial capital, where our families cultivated a value system related to resistance. In alignment with theory, and with our experiences, we elected to design items that capture intersecting forms of CCW capital (Yosso, 2005). Cognitive interviews were used to revise our drafted items and included students from a range of ethnic backgrounds, LGBTQ+ identities, and with a range of experiences (i.e., financial hardship, mental health, etc.). Students were asked to read items aloud and describe why they selected their responses. When students misunderstood a term, or when the items did not prompt the intended response, the interviewer took careful notes and discussed the item with the full research team. Items that arose repeatedly were revised for clarity and re-tested with a new group of students. We conducted 50 interviews that proceeded in five phases, where each phase included the feedback of approximately 10 students and included revisions from the previous phase. The finalized measure consists of 100 items on a 6-point response scale of agreement.

Contribution: Students from diverse backgrounds have strengths that have been unacknowledged or underappreciated by the dominant culture (Yosso, 2005). Through our work, we hope to challenge deficit narratives and shift the direction of policy discourse regarding student success. Our methodological approach integrates teachings from critical theories and relies heavily upon the voices of diverse undergraduates. Our approach has allowed us to develop items that better capture nuance in student experiences. There are few guidelines for
education researchers interested in conducting research in alignment with QuantCrit. We hope to provide an example for how researchers might choose to apply the tenets of QuantCrit to measurement development.

Comparing performance-based assessments of graph construction across biology subdisciplines.

Jaz Donkoh (SimBio)*; Eli Meir (SimBio); Lauren E Stoczynski (Purdue University); Emily Hutton (Purdue University); Nouran E Amin (Purdue University); Joel Abraham (CSU Fullerton); Ryan Baker (University of Pennsylvania); Stephanie M Gardner (Purdue University)

Abstract:
Study Context:
In recent years, there has been increased interest in teaching higher order, complex skills in introductory biology classrooms, such as experimental design or graphing. To address this need, we created a performance-based assessment for graph construction and interpretation for biology undergraduate students. The assessment uses a combination of graphing tasks, multiple choice and short answer questions to assess student graphing skills. The initial assessment used an ecology-based scenario in digital format. Since graphing can often be context specific (Roth and Bowen, 2001; Shah and Freedman, 2011 ), we expanded our assessment to include scenarios from these biology subfields: ecology/ evolution, cellular biology, and physiology. Here, we explore in what ways graph construction competencies vary across biology subdisciplines.

Research Design:
Each assessment scenario was designed to have the same structure: they all ask students to create graphs based on given predictions. Each assessment includes three graphing tasks, along with three intermediate constraint questions per task and five essay questions. In this talk we’ll present analyses of data from three scenarios drawn from three different subfields. Specifically, we examined the graphs students made using autoscoring algorithms that allow us to generate a total graph score and scores for seven graphing competencies. We collected data from 42 classes in schools ranging from community college to research universities, for a total of 2169 students. We ran a series of one-way ANOVAs to determine if student scores on graphing competencies differed between different scenarios. We also ran correlation tests to investigate the relationship across competencies within the three scenarios.

Analysis and Interpretation
When comparing graphing competencies across scenarios, we found that students had a significantly higher mean total score on the evolution scenario compared to the cell biology and ecology scenarios (F(2, 2111) = 37.02, p < 0.001). When comparing specific graphing competencies, we found that scenario mean scores differed most dramatically within graph type (F(2, 2111) = 31.27, p < 0.0001), data variability (F(2, 2111) = 51.70, p < 0.0001) and axes scaling (F(2, 2111) = 27.71%, p < 0.0001). Within scenarios, we found that total graph score correlates strongly with data variability and graph type competencies (both with r = 0.7), which are also correlated with one another (r = 0.625).

Contribution:
Constructing graphs is known to be difficult for students and the competencies needed for graphing vary by scientific discipline. Here we show that even within the discipline of biology, students’ competence in making graphs may differ based on the biological context. We also show preliminary data that suggest that some graphing competencies may be learned together, such as data variability and graph type. Understanding how the many competencies involved in
graphing relate to subfield and to each other can inform the design of better tools for teaching biology students to make graphs.

**Reading-to-learn scientific papers improves argumentation literacy and reading confidence.**

Meena M Balgopal (Colorado State University)*; Christine Folks (Colorado State University); Giovana Matos Franco (Colorado State University); Paul Ode (Colorado State University)

Abstract:

**STUDY CONTEXT**

Biologists may spend more time reading and writing than collecting data (Myers, 1990). Developing these disciplinary literacy skills helps biology students to 1) interpret scientific papers (Kararo & McCartney, 2019), 2) reinforce scientific identities (McDowell et al., 2023), 3) be more confident (Rawlings, 2019), and 4) become independent learners (Railton & Watson, 2005). To achieve this, students need help interpreting primary scientific literature (PSL) (Goller et al., 2021), and while helpful, annotation tools do not help with deconstructing scientific arguments (Kararo & McCartney, 2019). There remains a need for effective ways to improve argumentation literacy in biology courses (Lennox et al., 2020).

We used argumentation theory to examine how reading-to-learn (RTL) interventions help students deconstruct arguments in PSL. We used the Toulmin (1958) Argumentation Model (Lammers et al., 2019) that breaks arguments into 6 parts. Data (in results) support claims (in discussion), while qualifiers (methods and results) contextualize the strength of claims. Warrants (implicit or explicit) justify the data needed to support a claim (Kock, 2006). Backing statements support warrants using connecting words (e.g., such as, since). Rebuttals are counter claims or alternative explanations. Robust arguments include alternative hypotheses and more rebuttals (Erduran et al., 2004).

**RESEARCH DESIGN**

This exploratory mix-methods study tested whether RTL tasks using the Toulmin Model increased biology students’ 1) perceptions of the value of reading PSL, 2) reading confidence, and 3) performance in a sophomore-level Evolution course at a land-grant university. Students (n=240) participated in 4 RTL tasks – one every 3 weeks over 15 weeks: intro to RTL; hypotheses and claims; backing and rebuttals; 2 weeks of data interpretation. RTL tasks were explained in class and in a recorded video we posted online (i.e., Canvas) modeling the RTL task with an example paper. Students worked in randomly assigned groups in class to discuss the RTL task and associated paper (task 1: find 2-4 concepts in the paper that reinforce lecture topics; task 2: identify hypotheses or objectives in intro and the overarching claim in discussion; task 3: identify backing in intro, inductive or deductive reasoning, and rebuttal in discussion; task 4: how are figures referenced in text to support claims?).

We collected data on RTL content items on 4 exams (20% of multiple-choice exam questions assessed conceptual understanding of the PSL research), open-response short essays on a perception and confidence, and demographic data (gender, ethnicity, first gen status) with IRB approval. We used inductive semantic thematic analysis (Braun & Clarke, 2006) to assess perceptions and confidence in reading PSL. Two coders analyzed a random selection of 50 students. The initial interrater reliability of respective codebooks was 83% after which discrepancies were resolved to achieve complete agreement before coding was completed. Percentages of final themes were calculated and illustrative quotes were selected. We conducted repeated measures analyses to determine if student (across demographic groups) performance changed over time.
ANALYSES and INTERPRETATIONS
Overwhelmingly (96%), students reported positive perceptions of the RTL tasks. All tasks were mentioned at equal rates (~25%). Almost all students (94%) explained that tasks increased content understanding, of which most comments (87%) focused on genetics. Half the students (49%) wanted to keep improving reading skills, and 45% felt that RTL tasks helped them meet that goal. Two-thirds (67%) felt that RTL helped them understand science arguments, and 69% felt more confident overall, and 69% described graphical literacy specifically. A student shared: “it really challenged me to think about the concepts that I didn't quite grasp.” Some used the RTL tasks in other courses: “Thanks to the RTLs, I am used to applying outside papers to chemistry, and I did it without even thinking about it.” Students’ perceptions tracked performance. A repeated measures ANOVA indicated incremental increases in performance for all students by week 15 (univariate F3,229 = 11.92, P <0.001) regardless of gender (univariate time*gender: F3,229 = 1.67, P = 0.1737), ethnicity (univariate F6,231 = 0.88, P = 9124), or first gen status (univariate F3,229 = 0.44, P = 0.7252).

While biology instructors integrate PSL into courses, having interventions (like RTL tasks that deconstruct arguments) can help them support student learning (Hoskins et al., 2011). Interpreting arguments can help students also develop inferential reasoning, an integral component of demonstrating scientific literacy (Osborne, 2013). Our exploratory study provides promising evidence of an active learning strategy to increase argumentation literacy that we are testing across institutions and biology courses without associated recitations or labs.

Session 5_C
Exploring the costs of undergraduate research for low-income students.

Emma C Goodwin (Arizona State University)*; Sailor Dereadt (Arizona State University); Jasmine Goode (Arizona State University); Bec Kalfus (Arizona State University); Gailan Khanania (Arizona State University); Laura Pang (Arizona State University); Sara Brownell (Arizona State University)

Abstract:
Study Context: Participation in undergraduate research experiences (UREs) is known to be a positive and influential experience for science majors, and can increase motivation and interest in science, content knowledge and research skills, and retention in science (NASEM, 2017). However, these experiences have traditionally been available to students as an extracurricular experience, which students must seek out and often volunteer in during their free time (Bangera & Brownell, 2014). Guided by critical theory (Celikates & Flynn, 2023), we hypothesize that the structure of UREs presents inequities that systematically disadvantage low-income students from equitably participating in and benefiting from UREs. Through an interview study, we explored how the structure of mentored UREs challenge participation for low-income students and identify the factors that can mitigate these challenges.

Study/Research Design: The interview protocol and data analysis were informed by undergraduate members of the research team who participated in this work as part of a course-based undergraduate research experience, and who all had personal experience as undergraduate researchers from low-income backgrounds in a science faculty member’s lab. Interview questions were designed specifically to explore how students’ low-income background impacted their UREs. We recruited interview participants from a pool of nationwide survey participants, selectively contacting students who had 1) participated in mentored undergraduate UREs and 2) disclosed they were from a low-income background and/or had struggled financially.
in college. We conducted online interviews with 22 students from 16 universities.

Analyses and Interpretations: To develop the codebook, the research team iteratively read through interview transcripts, meeting regularly to draft and define codes that captured emerging ideas in the transcripts until saturation was reached. Once the codebook was finalized, each transcript was read and independently coded by four to six researchers, and all coding decisions were coded to consensus. After coding all 22 transcripts, members of the research team worked in pairs to review all coded segments and ensure that the codebook was applied consistently and accurately.

In interviews, nearly all participants framed time spent in UREs as a high-stress trade-off of time spent in paid employment, given students’ competing priorities of paying for tuition and meeting their basic needs. Even when students were paid for their research, students often needed to balance additional paid employment or encountered increased financial struggles because their research stipends were lower than what they would earn in an outside job. One participant explained: “Having three jobs sucks. That will take your energy out and not give you as much energy to devote to the research for sure.”

Participants also frequently explained that their commute was a significant limiting factor to their research participation, because they often lived further from campus in more affordable housing and/or relied on public transportation. Limited money for gas, the significant time it took to commute to campus, or limited access to public transportation meant that students sometimes had to limit their engagement in research activities or social activities with their research group. One participant, who could not afford to live near campus, explained, “For the students who live [close to] campus, going to the lab on a weekend is not that big a deal… But for me, it's a larger investment of my time and a lot of gas money… [There’s an] expectation [from my research mentor] that I can just drop everything and go into lab.”

Having a supportive research mentor who strived to understand their students’ experiences and respected students’ time and financial situation was often essential for low-income students to have a positive and productive research experience. Many participants explained that they were only able to participate in research because their mentors worked with them to develop accommodating research schedules. Most interviewees received financial compensation and/or earned course credits for their URE. In addition to helping them meet their basic needs and often enabling them to participate in research at all, students described that receiving financial compensation justified and validated their decision to dedicate more time and effort in a research experience.

Contribution: UREs can be costly activities for low-income students, and faculty, who often are from higher-income backgrounds, may not recognize the extra challenges that low-income students face in UREs. With this work, we will expand awareness of the ways that traditional mentored UREs may systematically disadvantage low-income students. We will also highlight what universities and research mentors can do to alleviate these challenges for low-income students and increase equitable research participation.

Bridging the Gap: Enhancing Research Lab Access Through Early Academic Pathway Intervention.

Joseph M Ruesch (Cornell University)*; Mark A. Sarvary (Cornell University)

Abstract:
In the context of an introductory biology course, where the foundational stones of scientific curiosity and understanding are laid, the decline in STEM (Science, technology, engineering, and
A unique challenge. We noticed that despite a high level of expressed interest in participating in research (77% in surveys conducted among our students), there was a significant disconnect between this interest and actual engagement in research labs (27% among exiting seniors). The reasons may be manifold: a lack of information about available opportunities, intimidation by the application process, and a perceived lack of readiness for research work. We hypothesized that students face many of these barriers when planning to join a research lab. To identify these challenges, our team conducted qualitative surveys in a large introductory biology laboratory course about students’ difficulties in finding a research lab (n=326 students). After coding responses, the most frequent challenges related to finding the right lab, stress relating to time management and underqualification, and concerns over communication with the potential labs in the various formats that may be required before joining the lab. We believe that many of these difficulties could be addressed with an early influx of information, peer mentoring, and some scaffolding of methods and techniques that have been successful before (Wilson et al. 2012; Zaniewski and Reinholz 2016).

Recognizing the critical role that early research experiences can play in inspiring and retaining student interest in the biological sciences (Seymour et al. 2004; Hunter et al. 2007; Russell et al. 2007; Eagan et al. 2013), we embarked on a strategic intervention designed to lower these identified barriers to entry for students seeking to engage in research labs. This initiative, rooted in the feedback from our students and the observed decline in STEM participation, both at large (Park et al. 2019) and in our own department, aimed to directly address the gap between student interest in biological research and their ability to access these opportunities.

The intervention comprising of the following four steps was implemented in an introductory biology laboratory course where the learning objectives include experimental design and science literacy training:

- Finding a research lab: Explore the research profiles of different professors on the institution’s website and select a lab of interest.
- Hearing about research choices and experiences from peers: Discuss research pathways and experiences with peers to gain information and insights.
- Creating a list of transferable skills gained: Recognize knowledge and skills gained through coursework, which could be highlighted during the interview process.
- Writing a cold email to apply to a research lab: Learn how to formulate an electronic communication to a new potential lab, including instructions and feedback on email formatting and expectations.

Each of these steps, taught throughout the semester, is aimed at explicitly addressing difficulties encountered by students and pulling content out of the hidden curriculum, allowing students the capacity to apply to research labs if they wish to join.

To assess the intervention’s outcomes, students were surveyed about their intended usage of the various steps. In the course, over the duration of three semesters, 1080 students (majority first-year students and biology majors) participated in the intervention, and 957 responded to an end-of-semester survey, expressing their future plans.

Students self-reported that 71% of them would make use of the skills to find a research lab, 63% would make use of the experiences shared by their peers, 61% would use the transferrable skills learned, and 64% would benefit from the email that they wrote. Additionally, findings indicate that a significantly larger percentage of first-year students, first-generation college students, and persons of ethnicity and race historically excluded from the sciences (PEER) were benefitted by the first step, that of finding a research lab (p=0.023, p=0.019, p=0.030) with PEER also benefitting more from experiences shared by fellow students (p=0.001) and recognition of their
developed transferrable skills (p=0.002). This implies a successful intervention, helping those who are just beginning on the pathway in looking and identifying a lab to join.

In conclusion, our initiative demonstrates the powerful impact of removing barriers to research opportunities for introductory biology students. By providing a clear, accessible pathway into research labs, coupled with supportive mentorship, we may be able to enhance student engagement and retention in the biological sciences. This model, though piloted within the context of an introductory biology course, holds promise for broader application across STEM disciplines, offering a scalable solution to the challenge of declining STEM engagement.

Pathways of opportunity in STEM: Comparative investigation of degree attainment across different demographic groups at a large research institution.

Robin Costello (Auburn University)*; Shima Salehi (Stanford University); Cissy Ballen (Auburn University); Eric Burkholder (Auburn University)

Abstract:
STUDY CONTEXT: Demographic identifiers influence the likelihood that a student graduates with a science, technology, engineering, and mathematics (STEM) degree (Seymour & Hunter, 2019). As such, promoting equity in STEM higher education requires an understanding of the factors underlying this disparity in STEM degree attainment. However, focusing on disparities centers students as solely responsible for improving their own educational outcomes and downplays systemic inequities (Shulka et al., 2022). An opportunity gap framework shifts focus to the structural deficits of institutions and classrooms that produce STEM degree attainment inequities (Carter & Welner, 2013). In this study, we used an opportunity gap framework to analyze the pathways through which students enter into and depart from STEM degrees in a large, research-intensive (R1) higher education institution and to better understand the underlying factors responsible for demographic disparities in STEM degree attainment. Work that identifies the explanatory mechanisms through an opportunity gap framework is rarely done and vital for understanding the institutional and classroom interventions most likely to disrupt inequities in STEM education.

STUDY DESIGN: We investigated whether observed demographic disparities in STEM degree attainment at an R1 higher education institution were due to (1) lower intent to pursue STEM degrees or (2) disproportionate academic challenges among women, persons excluded because of their ethnicity or race (PEERs), and first-generation students. To test these hypotheses, we used structural equation modeling to analyze institutional enrollment and demographic data from 14,738 students with the goal of identifying explanatory mechanisms for disparities in 6-year STEM graduation rates.

ANALYSES AND INTERPRETATION: Structural equation modeling revealed that equity gaps in STEM graduation rates were mediated by factors that differed across demographic groups. The gender disparity in STEM degree attainment was explained by disparities in students’ intent to pursue STEM at the beginning of college. Women were half as likely as men to intend to major in a STEM field as incoming first-year students (p < 0.0001), and this translated into a lower likelihood in attaining STEM degrees, as students intending to major in STEM fields were nearly 4 times more likely to graduate with STEM degrees (p < 0.0001). Unlike women, PEER and first-generation students had first-year GPAs that were 0.3
and 0.2 standard deviations, respectively, lower than their white and continuing-generation counterparts (p < 0.0001). This lower academic success translated to lower graduation rates in STEM, as students were 2.5 times more likely to graduate with STEM degrees for every standard deviation increase in their first-year GPA (p < 0.0001). Academic challenges during the first year of college persisted for PEER and first-generation students even when structural equation models accounted for disparities in academic opportunities experienced prior to college, emphasizing that first-year courses and the higher education system failed to equally support all students pursuing STEM degrees.

CONTRIBUTION: Overall, our findings support the idea that patterns of departure from STEM pathways differ among demographic groups. To promote equity in STEM, it is critical that we understand these differing patterns and respond with structural efforts designed to support different student identities. As many students, both STEM and non-STEM students, enroll in introductory and non-major biology courses, this work should be of general interest to SABER attendees. These results specifically imply that curricular modifications to biology courses that (1) engage and encourage women to pursue STEM and (2) provide academic support for PEER and first-generation students will best narrow current equity gaps.

Comparing Self-reported Impacts of Scientist Spotlights in Lower- and Upper-Division Courses.

Shaelin Chong (UC San Diego)*; Jerick Kim (UC San Diego)*; Melinda T Owens (UC San Diego)

Abstract:
Study Context: The Scientist Spotlight is a homework assignment featuring a counter-stereotypical scientist's personal and scientific story (Schinske et al., 2016). They have been shown to decrease student's stereotypes about scientists and increase student perceptions of how relatable scientists are, student’s sense of their ability to do science, and course grades (Schinske et al., 2016; Ovid et al., 2023; Yonas et al. 2020). Researchers have sought to understand these effects through the framework of “possible selves,” which are student “hopes, fears, and fantasies” that they use to define themselves (Markus & Nurius, 1986). Student exposure to stereotypes can narrow their possible selves to exclude scientific careers, while exposure to counter-stereotypical representations can broaden their possible selves (Wonch Hill et al., 2017; Cheryan et al., 2013). Accordingly, most of the research on Scientist Spotlights has focused on non-majors or introductory biology students, who are presumably still forming their biology identities and career plans (Dika and D’Amico, 2016). However, Aranda et al., 2021 found significant effects of Scientists Spotlights on scientist relatability in a sample including upper-division students. We hypothesized that upper-division students exposed to Scientist Spotlights would still experience effects but that the effects would vary between students at different stages of their undergraduate careers.

Research Design: We asked what proportion of students in lower- and upper-division courses mentioned Scientist Spotlights and cited ideas related to “diversity in science,” “self-efficacy,” and “humanizing scientists” in an end-of-course reflection. We also asked whether these ideas appeared more frequently in students from minoritized groups. Data was collected from students taking two introductory and one upper-division biology course for majors at a large, public, diverse West Coast university (n=765 over two quarters per class). Students in introductory course B were exposed to either 7 or 8 Scientist Spotlights, while students in introductory course A and the upper-division course were exposed to 4 Scientist Spotlights over a 10-week quarter. At the end of the term, they were asked to write >800 words in response to the Final Reflection prompt, “What did you learn from your experiences in [course] this quarter that will continue to
influence you for many years to come?” In addition, we collected demographic information regarding ethnicity, race, gender, and first-generation college-going status from a pre-course survey. We used deductive coding related to the themes “diversity in science,” “self-efficacy,” and “humanizing scientists,” taken from Rivera et al., 2023, to analyze the parts of Final Reflections related to Scientist Spotlights. “Diversity in science” referred to students discussing ways in which scientists were diverse, “self-efficacy” referred to discussing ways in which they or other people were capable of being scientists, and “humanizing scientists” referred to discussing ways in which scientists were relatable. For inter-rater reliability, we used an iterative process where two coders coded 10% of the Reflections to see if they agreed at least 85% of the time for each code. Finally, to analyze differences in the effects of the Scientist Spotlights among various students, we used chi-square tests to compare the frequency of mentioning Scientist Spotlights or citing various themes between students in different courses and demographic groups.

Analyses and Interpretations: Students in introductory course B, with double the number of Scientist Spotlights, were significantly more likely to mention Scientist Spotlights than those in introductory course A or the upper-division course (introductory course B: 47% (98/208) vs. introductory course A: 35% (113/321), (p=0.019) and vs. upper-division course: 33% (77/236), p=0.005). Of students who did cite Scientist Spotlights, upper-division course students were just as likely as introductory course students to cite codes relating to “diversity in science” and “humanizing scientists” (p>0.12 for all comparisons) but were less likely to cite codes relating to self-efficacy than in introductory course B students (p=0.024). We did not find any differences in the frequencies of mentioning Scientist Spotlights or of mentioning certain themes by demographic group.

Contribution: Our study adds to the literature examining myriad effects of Scientist Spotlight assignments on students. Even in a course with only four Scientist Spotlights or with upper-division students who presumably have a stronger science identity, over 30% of students claimed that Scientist Spotlights were an influential part of the course. However, lower-division students were more likely to cite self-efficacy-related codes than upper-division students. These results suggest Scientist Spotlight can have different impacts at different levels of biology education.

Session 5_D

Navigating across the DNA Landscape: Student sketches reveal molecular biology misunderstandings related to scale and abstraction.

Crystal Uminske (Rochester Institute of Technology)*; Dina Newman (Rochester Institute of Technology); Kate Wright (Rochester Institute of Technology)

Abstract:
Study context: There are dozens of ways that biologists use visual representations to teach and communicate about concepts in molecular biology. Representations can include lines, letters, and ladders, as well as boxes, strings, and maps. To appropriately interpret and use these varied representations, students need to develop skills in visual literacy (Trumbo, 1999). Such skills include applying content knowledge to decipher symbols and evaluating the strengths and limitations of visual representations (Arneson & Offerdahl, 2018). The development of these visual literacy skills is constrained by students’ ability to reason across levels of biological organization and levels of abstraction (Schönborn & Anderson, 2009; 2010). We can operationalize these levels of biological organization and abstraction using the DNA Landscape framework (Wright et al., 2022), which categorizes visual representations of DNA in a 3-by-3 matrix.
matrix to show variation in visual representations across different scales (nucleotide, gene, and chromosome) and across different levels of abstractions (very abstract, elements of shape and abstraction, and literal shape).

Study design: We hypothesized that students may struggle to correctly interpret and apply their molecular biology knowledge when working with visual representations at varying scales and levels of abstraction. To better understand how students are engaging in visual literacy skills across the levels of scale and abstraction within the DNA Landscape, we conducted 35 semi-structured interviews with undergraduate students at two institutions. We developed our interview protocol using the Visualization Blooming Tool (Arneson & Offerdahl, 2018) to target students’ visual literacy skills at specific levels of Bloom’s Taxonomy (Bloom et al., 1956). We targeted the lower-order visual literacy skills (Remember and Understand) by asking students to produce sketches of nucleotides, genes, and chromosomes, and targeted higher-order visual literacy skills (Analyze and Evaluate) by asking students to compare, contrast, and critique diagrams from published biology concepts assessments which represented nucleotides, genes, and chromosomes at varying levels of abstraction (Beckham et al., 2023; Couch et al., 2015, 2019; Smith et al., 2008).

Analyses and Interpretations: The 35 students we interviewed generated over 400 sketches of molecular biology concepts. When comparing students’ verbal descriptions of nucleotides, genes, and chromosomes to their sketches, we often found that students knew the correct vocabulary to describe molecular biology concepts but their sketches uncovered incomplete understandings of these same concepts. We found that 54% of students (n = 19) had unrealistic conceptions of biological scale in at least one of their sketches, such as representing an exon as a single nucleotide. We also found that 48% of students (n = 17) had at least one sketch with unexpected or non-canonical mixings of symbols across the levels of abstraction, such as placing letters representing nitrogenous bases along what is typically represented as the sugar-phosphate backbone in a double helix. In total, the majority of students (69%, n = 24) drew sketches that revealed incomplete understandings of molecular biology concepts related to scale and/or abstraction.

Contribution: Our work highlights the utility of the DNA Landscape (Wright et al., 2022) as a tool for research and teaching, and our qualitative study expands upon the quantitative findings in Arneson & Offerdahl (2023), which indicated that visual representations in molecular biology are cognitively demanding. Using the DNA Landscape as a lens for our analysis, we found that the majority of students held incomplete ideas about biological scale and often misunderstood abstract representations in molecular biology. This finding emphasizes the importance of explicitly explaining and providing scaffolding when using diagrams and figures in instruction and assessment. Based on these results, we suggest that biology instructors pay particular attention to delineating the symbols, notations, and conventions that are to visualize molecular biology topics and we recommend that instructors teach with a range of visual representations that present molecular biology topics across the levels of scale and abstraction within the DNA Landscape.

Analyzing Undergraduate Student Experimental Design Using a Card Sorting Tool.

Colin Harrison (Georgia Tech)*; Megan Cole (Emory University); Clarke Britton (Georgia Tech); Hannah Shin (Georgia Tech); Yassin Watson (Georgia Tech); Denver Roberts (Emory University); Peter Rubin (Georgia Tech); Zoya Mir (Georgia Tech); Katy Suh (Emory University)
Abstract:
Study Context
Measuring student growth in laboratory experimental design skills can be a challenging and time-consuming process. Novices and experts approach issues related to experimental design in much different ways. Previous studies have demonstrated the measurement of conceptual skills and shifts in those skills over time (Deane et al. 2014, Gormally et al. 2012, Sirum and Humburg 2011, Lederman et al. 2002). However, these studies fail to address how novices organize concepts related to experimental design and how that is different than what is seen in experts.

Card sorting tasks have proven to be useful tools when measuring differences in the ways in which experts and novices organize their information (Lin & Singh 2010, Mason and Singh 2011, Smith et al 2013, Irby et al 2016, Krieter et al 2016, Bissonnette et. al 2017). We developed a card sorting task that measures the differences in the way experts and novices organize their knowledge of experimental design (Cole et. al 2023).

Study/Research Design
We designed a 16-card sort examining experimental design skills that included proposed deep feature pairings (research approach) and two different surface feature pairings (organism studied and person doing the research). This test was validated through expert focus groups and novice trial studies and then implemented in an academic setting. To test the differences in the ways novices and experts performed on the task, first-year biology major students were given the test as part of their introductory biology lab curriculum (n= 569). Faculty, postdocs, and graduate students were recruited to measure task completion at different levels of experience (Faculty/postdoc n = 11, graduate students n = 10). All groups were measured in a unframed and framed sort (deep feature categories given). A separate cohort of undergraduate students completed the task at the beginning of their first semesters on campus, at the beginning of their second semester on campus and at the end of their second semester (n = 333, unframed only). In addition, we performed the card sorting task on a group of advanced biology students and students currently participating in research (ongoing).

Analyses and Interpretation
To ascertain differences in sorting we measured the edit distance (amount of card moves to get a perfect sort) from both deep feature and surface feature conditions for all studied groups. In the unframed sort, undergraduate students sorted more like novices with an average deep feature and surface feature edit distance of 7.7 and 7.7 respectively While faculty/postdoc sorted like experts with an average edit deep feature edit distance and surface feature edit distance of 2.8 and 9.9 respectively. Graduate students were intermediate for both average deep and surface edit distance (6.2 and 8.1) with large variation in scores. In the framed sort edit distance to the deep feature sort dropped across all groups with the difference in undergraduate scores being statistically significant (7.7 to 5.2, p<.0001). Deep feature edit distance was lower in students with a 4 or better on the AP Bio exam and non-PEER students edit distance was significantly lower than PEER students in the framed sort. Written responses were analyzed via a rubric to measure how often participants discussed expert-like, developing, or novice-like responses. Rubric scores for individuals correlated with their calculated edit distance, with participants expressing novice-like responses having a higher edit distance (Cole et al. 2023). Early analysis undergraduate biology majors as they matriculate through their first year on campus show no significant difference in their edit distances over this time period.

Contribution
This study successfully demonstrates the differences in the way in which experts and novices organize their information. This tool can be used to measure and identify students that may be
struggling with the experimental design skills and help them towards a better framework to build as they move through their academic careers. While we have not been able to measure differences in the overall edit distance during biology majors’ first semester on campus, subsequent studies into advanced biology students can help illuminate the scholastic activities that take place during an undergraduate’s career that helps shift them closer to expert-like organization.

**Defining and Measuring College STEM Student Trust in Their Instructor Using a Process Model Approach.**

Kathy Zhang (Yale University)*; Julia Gill (Cambridge University); Tong Zhang (Duke Kunshan University); Lia Crowley (Baruch College); Henry Wagner (Yale University); Juliette Bennie (Yale University); David Hanauer (Indiana University of Pennsylvania); Xinnian Chen (University of Connecticut); Mark Graham (Yale University)

**Abstract:**

Study Context: Previous work has shown that personal connections between students and instructors can improve a range of learning outcomes, such as motivation to engage (Komarraju et al., 2010) and self-efficacy (Ballen et al., 2017). The trust between students and instructors underlying the development of personal connections may thus be an under-researched step to achieve such outcomes, particularly in student-centered classrooms utilizing evidence-based teaching practices (EBPs) (Freeman et al., 2007). Indeed, our recent work shows that student trust is significantly positively associated with greater engagement, course performance, and intent to persist in STEM, mediated by students’ commitment to engage in, or “buy-in” to, EBPs (Cavanagh et al., 2018; Wang et al., 2021). The promise of these findings warrants a more thorough investigation of how college students develop trust in an instructor. Though there is a body of research defining trust in K-12 settings (Tschannen-Moran & Hoy, 2000), there is a comparatively extant literature on the nature of student trust in higher education. In our previous work, student trust was operationalized by adapting a close personal relationship theoretical framework of acceptance, care, responsiveness, and understanding (Clark & Lemay, 2010), but it is unclear whether this framework fully captures the nature of student-instructor relationships in large-enrollment classrooms. Moreover, existing measures of student-instructor trust lack consensus on an operationalization of student trust in the college STEM environment (Hagenaeur & Volet, 2014). Study Design: Here, we seek to operationally define and reliably measure undergraduate students’ trust in their STEM instructor. We follow what is called a “process model approach” to instrument design and validation (Chatterji, 2003), which advocates for progressive steps to 1) identify a domain of interest, 2) build a taxonomy to define the domain, and 3) use the taxonomy to write items and iteratively design an instrument. By building items from a taxonomy, the process model approach to instrument design promotes the achievement of a succinct factor structure in fewer iterations of validation (Graham et al., 2009). To build a multi-dimensional taxonomy of trust, we conducted a literature review and interviews with 57 students enrolled in large STEM classrooms - of whom more than half self-identified as members of historically marginalized groups - to identify instructor characteristics associated with building student trust. Our resulting taxonomy of trust served as the foundation for developing a Trust and Responsiveness in Undergraduate STEM Teaching (TRUST) instrument. Analyses and Interpretation: Based on the process model approach (Chatterji, 2003), we used a stepwise data-driven coding process to identify themes in students’ open-ended responses about how they interpreted trust in their instructor and summarized our analyses in a detailed qualitative codebook of trust. The resulting codebook contained 27 unique codes matched with instructor characteristics perceived as being trustworthy by students, and was organized into three domains: affective, relational, and cognitive trust. Instructor characteristics such as having a

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positive attitude fell under the domain of affective trust, characteristics such as expressing an interest in students’ lives fell under relational trust, and characteristics such as maintaining transparent communication fell under cognitive trust. The qualitative codebook both confirmed and expanded upon our previous definition of trust based on the close personal relationship framework and existing definitions found in our literature review. Following the process model approach, we then built instrument items using emergent codes. For example, for the code describing transparent communication with students, we developed a corresponding instrument item, “My instructor clearly communicates class expectations.” Our initial 33-item instrument was distributed for exploratory and confirmatory factor analyses to a total of 1,891 students. The final 27 items were captured by a six-factor structure that aligned with the taxonomy of trust from which the items were initially derived with good model fit ($\chi^2 (309) = 253.4$, $p < 0.001$, TLI = 0.92, CFI = 0.93, RMSEA [90% CI] = 0.067 [0.064, 0.069], SRMR = 0.05). A manuscript describing the validation of the finalized TRUST instrument is in process. Contribution: By developing and using a taxonomy with clear empirical and theoretical underpinnings to build a measure of student’ trust in their instructor that achieved coherent factor structure with minimal iterations of item editing, we demonstrate the advantage of the process model approach to instrument design in higher education research settings. Our work further informs novel and actionable interventions to enhance the effectiveness of EBPs for positive student outcomes through building student-instructor trust.

Context matters when assessing science civic engagement in science literacy students.

Jen Teshera-Levye (East Carolina University)*; Jenny M Dauer (University of Nebraska-Lincoln)

Abstract:

Study Context
To face global socioscientific issues (SSI), students require both science literacy skills and ability to apply those skills in their communities. Science educators are therefore increasingly concerned with fostering science civic engagement, or the ability to apply science skills to improve society (Adler & Goggin, 2005; Rudolph & Horibe, 2016). We explore the development of students’ science civic engagement as they learn scientific decision-making skills. Alam et al. (2022) developed a framework for science civic engagement (SCE) that includes four core domains, measured by the Predictors of Science Civic Engagement (PSCE) survey. The PSCE can be flexibly contextualized around a specific issue or a specific community. In previous work, we found that only the knowledge domain of the PSCE increased after a semester-long science literacy course contextualized in a students’ chosen community.

Successfully developing students’ science civic engagement through classroom activities relies on learning transfer, the ability to use skills learned in one context and apply them to another. The context in which knowledge is introduced plays an important role in the ability to transfer that knowledge (Bransford et al., 2000). Specific contexts are important for knowledge retention and application (Klassen, 2006), but learning may be so tightly connected to the context that it does not readily transfer to another (Bransford et al., 2000). Here we consider transfer of SCE between SSIs studied in class, unfamiliar SSIs, and general community contexts.

Design/Procedure
In this study, we administered the PSCE instrument to students enrolled in a science literacy course which uses SSIs to teach science-informed decision-making. Students completed the PSCE survey as part of pre-course and post-course assignments. The survey was administered in three modalities: in the context of two communities, in the context of the two SSIs taught that semester, and in the context of one community and two SSIs, one familiar to students and one
unfamiliar. We compared pretest to posttest for all survey contexts (paired t-tests) and compared pretest and average pre-to-post change between community and topic-based surveys, and between familiar and unfamiliar topics (Welch's two-sample t-test).

Analyses and Interpretation
We found that the survey context (community or topic) had a significant effect on both pre-test scores and the change over the semester. All four domains of pre-test PSCE were higher in the community contexts compared to the topic contexts (p < 0.001 for each construct), while there were no differences between topics or communities. However, the pre-to-posttest change was higher for the topic-based survey compared to the community-based survey (p < 0.001 for each construct). Community-based SCE only increased in the civic knowledge domain over the semester (p < 0.001), while all four constructs increased significantly on the topic-based surveys. While there were no differences between specific topics, we did observe were significant differences when comparing SCE framed around the topic students studied compared to the topic they did not. Efficacy (p = 0.03, t-test) and action (p = 0.06, t-test) were higher in the studied topic than the transfer topic, while knowledge and values were not different.

These results together suggest that students transfer science literacy skills from the course to civic engagement when kept within the contexts those skills were learned (i.e., specific SSIs). In this case, community-based SCE does not change because the context of the survey is too different from the context of the classroom. Increased familiarity with a particular topic may also be a factor, as changes in civic efficacy and action were larger with a studied SSI compared to a new one.

Contribution
These results show that context matters when evaluating scientific civic engagement in students. Students initially show higher predictors of civic engagement when asked to think about their communities than specific SSIs, but PSCE only increases in the issue-based context. This occurred whether or not an issue was studied in class, though familiarity with the topic lead to larger increases in civic efficacy and civic action. Researchers should be mindful that, when placed in the context of an SSI, the PSCE may be reflecting a change in content knowledge rather than a true increase in civic engagement.

The goal of SSI-based science literacy education is not to teach students about the handful of issues covered in the class, but rather for them to be able to leave the course able to apply these skills to new problems, i.e., to use science skills to engage civically. If the change in topic-based SCE is due to easier transfer rather than topic familiarity, it will also be important to understand how to then enable that transfer when assessing civic engagement in a community context rather than an issue-based one.
ROUNDTABLE ABSTRACTS

Roundtable 1: Exploring the Impact of Collaborative Educational Models on Biology Undergraduate and Faculty Development
Kristine L Callis-Duehl (Donald Danforth Plant Science Center)*; Precious Hardy (Donald Danforth Plant Science Center)

Abstract:
Study Background: Integrating public-private partnerships (PPPs) in biology education has emerged as a strategic approach to address the evolving needs of undergraduate students and faculty development (Siraj, 2023). This research-in-progress aims to investigate how PPPs can bridge gaps in resource availability and pedagogical innovation. Current literature suggests that PPPs can potentially enhance biology students’ experiential learning opportunities and industry readiness. Yet, there is limited research on their direct impact on educational outcomes (Khallaf et al., 2022; LaRocque, 2008; Roehrich et al., 2014). This research is grounded in the existing discourse on collaborative education models from other disciplines, such as finance and healthcare (Dzhikiya et al., 2023; Jensen, 2016). It addresses the noted gap concerning the systematic evaluation of PPPs in biology education and their implications for teaching and learning. (Dzhikiya et al., 2023; LaRocque, 2008)

Research Question: The central question explores the impact of PPPs on undergraduate education and faculty professional development. This study aims to identify effective PPP practices, assess their scalability, and evaluate the associated challenges (Khallaf et al., 2022; Siraj, 2023)

Engagement in Discussion: The roundtable will engage participants through a series of directed questions designed to elicit personal experiences, perceptions, and insights on implementing PPPs in biology education. An interactive brainstorming session will facilitate the generation of additional research questions and potential methodologies. Participants will receive a summary outlining existing PPP models’ objectives and preliminary impacts.

Desired Feedback: Feedback is sought on the following aspects:
• Methodological approaches for measuring the outcomes of PPPs.
• Identification of success indicators for PPPs in biology education.
• Strategies for applying PPP models across different educational contexts.

Contribution
This roundtable is expected to be highly relevant to SABER attendees, particularly those interested in innovative educational models, undergraduate science education, and faculty development. The study holds the potential to inform best practices for implementing PPPs in biology education, thereby contributing to the broader conversation on improving educational outcomes and preparing students and faculty for the challenges of modern biological sciences (Roehrich et al., 2014).

Roundtable 2: Preparing Underrepresented Students: Employing the Power of Undergraduate Research to Generate Motivation for Successful STEM Students
Matthew Blank (Baylor College of Medicine)*; Curtis Henderson (Houston Christian University); Illya Medina Velo (Houston Christian University)
Abstract:

While under-represented minorities (URMs) in the US STEM workforce have slowly increased toward proportionate representation (SSTI Report 2023), there is still significant improvement to be made. Our work investigates the collective impact of three unique undergraduate authentic research experiences (UREs) on student retention in STEM education-to-career pathways. Our work includes the implementation and analysis of two NSF-funded projects (described below) and one proposal currently under review. We offer this topic as a roundtable discussion for investigators in STEM education pathways to share insights and ideas across institutions to improve methods and analyses for corresponding URE projects.

The RAMP to Research Project provides undergraduate fellows with year-long preparation for a 10-week summer research experience at a notable university cancer center. The Cell and Mol Lab Project offers a laboratory co-requisite course to accompany a sophomore-level Cell and Mol lecture course, with students participating in discovery-based research as they practice lab techniques and skills. Both projects used the survey instrument developed by Chemers et al. 2011 to measure pre- and post-intervention self-confidence, identity, and efficacy, with three years of results from the RAMP Project indicating marked increases in belonging and confidence and year-one results from the Cell and Mol Lab Project indicating increases in belonging, confidence, and success in the overall course.

We seek feedback on a current proposal to develop, implement, and assess a pilot program designed to increase STEM pathway persistence and retention of undergraduate learners struggling in foundational STEM courses at partner Minority Serving Institutions (MSIs). The program will leverage the expertise of a medical university with a robust research portfolio to recruit 12 first-year students from two partner MSIs and engage them in evidence-based activities to boost STEM retention and prepare them for undergraduate research experiences later in their undergraduate careers. We will facilitate discussion and solicit feedback on 1) mentoring mechanisms of underprepared learners, 2) undergraduate research models for underprepared learners, and 3) survey instruments and feedback mechanisms used by researchers for this unique undergraduate population.

Roundtable 3: Teaching Experimental Design in Undergraduate Introductory Biology for Transfer of Learning to Scientific Literacy
James Cerven (Dominican University); Christopher Anderson (Dominican University); Carissa Buber (Dominican University); Scott A Kreher (Dominican University)*

Abstract:
A core concept of the natural sciences, including biology, is the use of empirical evidence in testing hypotheses and construction of explanations. As a consequence of the centrality of empirical evidence, experimental design skills and understanding of the logical basis of experimental design are central recommendations in learning guides, such as Vision and Change and the K-12 National Research Council Framework. However, in previous discipline – based education research, we and others have found that undergraduate students have major gaps in their understanding of the logical basis of experimental design, even after exposure to controlled experiments in teaching labs. Furthermore, extensive research from cognitive psychologists has demonstrated that understanding controlled experiments is a cognitively difficult task and without deliberate teaching, people can be left with inadvertent gaps in their understanding of a fundamental concept in biology and the natural sciences. This last point deserves special consideration: while all students who complete STEM degrees should achieve
understanding of experimental design, all people should have some understanding of the logical basis of experimental design and should be able to apply these logical concepts to their everyday lives, which is a form of scientific literacy.

Our ongoing research program has three objectives:
1. Better research on how undergraduate students in introductory biology understand controlled experiments.
2. Creation of an intervention, that can be deployed in lecture and lab, to improve experimental design skills.
3. Testing for transfer of learning between experimental design skills and scientific literacy skills.

Our project is ongoing, but community feedback will improve the quality of data and will allow us to craft an intervention that is more usable and useful. The session handout will outline the questions below.
1. What types of exercises and activities would be useful for you in undergraduate introductory biology, lecture and lab, that would be useful for teaching about controlled experiments?
2. Experimental design is a complex set of skills. What are the best ways to assess this skill?
3. We are interested in how better understanding of experimental design can allow transfer of learning to scientific literacy skills. What are some related scientific literacy skills that would be useful to assess?

Roundtable 4: Improving teamwork in undergraduate research-based courses: Tools from team science
Heather D. Vance-Chalcraft (East Carolina University)*; Fiona Freeland (East Carolina University)

Abstract:
Study background: Students are often expected to work in groups during lab courses, commonly resulting in conflicts and unequitable workloads among group members. Despite these challenges, students are rarely given training in how to work together effectively. Prior studies have examined aspects of group size, group formation, and group duration (Wilson, Brickman, & Brame, 2018), but little research exists on the efficacy of using tools from the team science literature (National Research Council, 2015) with biology students to attain competencies needed for productive team dynamics.

Description of Research Ideas and Desired Feedback: This roundtable session will describe research to determine whether tools created from the team science literature are successful in building an undergraduate student's team competencies. Eighteen research-based courses are currently using these tools and participating in evaluation efforts. These tools include communication and research planning documents, training materials on team science and conflict resolution, and general information sheets on team science. Participants in the roundtable session will be given a one-page summary of these tools, along with a series of discussion questions about the applicability of these materials to a variety of course contexts and the utility of these tools. Ideas for additional tools that would be useful in improving student team experiences in courses will also be solicited, along with ideas for other ways to evaluate the tools.

Participatory Component: Roundtable discussion will include a series of think-pair-share exercises about common issues that arise in student groups, how and whether the team science tools would help prevent these problems, and how the tools should be revised. In addition to the one-page summary of the existing tools, a QR code will be provided to access full versions of our draft team science training program. A follow-up large group discussion will
examine our evaluation plans.
Contribution: While these tools were designed for research-based courses, they could be applied in any lab or lecture course that utilizes group work. Roundtable discussion will help project personnel to refine the tools and their evaluation plan, while giving participants ideas of how to improve team dynamics within their student groups. Participants will be able to access these tools after the session to improve the use of group work in teaching.

Roundtable 5: Exploring the Impact of CUREs on Pre-Service Elementary Teachers: Science Affinity, Motivated Learning Strategies, and Perceptions of Instructional Support
Amandeep Kaur (Texas State University)*; Carrie Bucklin (Texas State University ); Kristy Daniel (Texas State University); Sunni Taylor (Texas State University)

Abstract:
My study will investigate the changes in student’s self-regulated learning, feelings and cost of belonging, and development of a scientific identity after participation in a Course-Based Undergraduate Research Experience (CURE) developed for a non-major, general science course for pre-service elementary teachers (PSET). Additionally, we will examine how Student Instructional Assistants for the course implemented their pedagogical training, compared to what was taught during their professional development training sessions. Typically, PSETs are rigorously trained in educational practices, with limited course work in specific content (i.e., science). When they enter their K-12 classrooms, they are required to teach english, history, science, and mathematics. However, these students lack confidence in science content and skills, feeling uncomfortable teaching it. This results in limited dedicated science instructional time.

One way to increase student’s content and skills in any area is through authentic research experiences (AREs). Additionally, AREs increase interest, connection, and scientific identity, particularly with non-science majors (Strayhorn, 2012). There is limited space for non-major students to participate in AREs through a traditional mentorship model, these spaces are typically allocated to undergraduate or graduate majors. Implementation of a CURE integrates ARE practices into undergraduate STEM education (Bangera & Brownell, 2014). CUREs can lead to an increase self-regulated learning, scientific identity, and pedagogical approaches. There are a limited number of studies investigating if this holds true for non-major, PSETs as well as undergraduate biology majors. My study will seek to fill this gap.

Roundtable participants will be divided by experience to encourage diverse discussion. The participant handout will be an infographic illustrating research questions, conceptual frameworks, and methodology. I will request feedback on my selection of conceptual frameworks, current data sources, and methodologies, with suggestions for improvement. SABER roundtable attendees will help inform a new branch of CURE research (e.g., pre-service elementary) and discuss the current model and limitations of pre-service elementary training programs. This project may act as an intermediate step to reimagine how we train PSETs to teach science content in their future classrooms, thus resulting in improvements in student engagement and learning outcomes.

Roundtable 6: Preparing Community College Transfers for Graduate School: Graduate Faculty Perspectives on CURES as Research Experience
John Espinosa (UC Merced)*; Marcos García-Ojeda (University of California, Merced)
Abstract:
Study Background: Undergraduate research experiences (UREs) are a high-impact practice that promote learning and persistence for students, including those from underrepresented backgrounds, and serve as a key stepping stone to graduate school (Hernandez et al., 2018). Unfortunately, these experiences are not always available to Community College Transfer Students (CCTS), who disproportionately come from underrepresented backgrounds and face barriers to research participation (Battaglia et al., 2022). Course-based Undergraduate Research Experiences (CUREs) are one proposed way of increasing research access but it is unclear if students get similar benefits of a mentored URE or if CUREs are valued the same by graduate admissions panels (Cooper et al., 2021). Further research is essential to understand the impact of CUREs on the pipeline from community colleges to graduate schools and to explore how different types of research experiences enhance the likelihood of transfer students gaining admission to graduate programs. (Van Nguyen et al., 2023).

Description of Research Ideas and Desired Feedback: Our overarching research question is: How do different types of UREs, specifically mentored research vs CUREs, impact CCTS’ preparation for and admission to graduate school? We will approach this topic in three ways; 1) Interview current STEM graduate students who transferred from community colleges to explore how they accessed undergraduate research opportunities and discussed these experiences in their graduate school applications, 2) Survey current transfer students in CUREs and UREs regarding their knowledge of research experiences through the lens of Scientific Research Cultural Capital (Cooper et al., 2021), and 3) Interview Biology Graduate Admission Committee Chairs to understand their perceptions of CUREs as a means of graduate school preparation. We hope to receive feedback on our data collection and analysis methods and project alignment. Additionally, we seek collaborations to expand participant recruitment beyond our institution.

Participatory Component: Participants will receive a handout featuring a flowchart of our proposed research questions and methods. After briefly explaining our project we will utilize think-pair-shares to elicit feedback on specific questions before opening it up to general comments.

Contribution: This roundtable will be relevant to SABER attendees interested in promoting the inclusion of CCTS in research experiences, and those concerned with the use of CUREs as a supplement to UREs.

Roundtable 7: Curriculum Reform that Fosters Equity and Inclusion
Anastasia Chouvalova (Texas Tech University); Adriel Cruz (Sierra College); Nicole Scheuermann (Northern Illinois University); Ariel Chasen (University of Texas Austin); Dawn Foster-Hartnett (University of Minnesota Twin Cities); Cathy Ishikawa (California State University Sacramento); Brock Couch (Loyola University of Maryland); Ashli Wright (The Ohio State University); Erika L Williams (North Carolina Agricultural and Technical State University); Justine S Liepkalns (Colorado State University); Bailey Von der Mehden (University of Tennessee Knoxville); Andrea Schnitz (Southwestern College); Amanda G Conner (Georgia Southern University); Beverly Smith-Keiling (University of Minnesota Twin Cities); Clark R Coffman (Iowa State University)*; Mike Klymkowsky (University of Colorado Boulder); Teri Balser (University of Calgary)
Abstract:
Background: An often overlooked area of diversity, equity, and inclusion that directly impacts students is overall course and curriculum design. In recent years, there has been more focus on the impact of pedagogical practices than curriculum in biology education research (Aikens, 2020; Felder & Brant, 2024). Course and curricular design’s discriminatory effects on underserved student groups is gaining recognition (Matz et al., 2018, Harris et al., 2020). In chemistry and biology, emphasis is often on proficiency in calculations, rather than scientific understanding (Stowe et al., 2021, Ralph et al., 2022, Klymkowsky, 2023). Klymkowsky et al. (2017) argue that curricula should revolve around core skills and avoid producing conceptual vacuums, which often result from teaching a series of isolated topics. Efforts to diversify curricula, use inclusive, open education resources, flexibility of course offerings, and awareness of implicit assessment biases can result in more inclusive courses and curricula. Institutions should be encouraged to rethink their curricular requirements so that curricular reform reaches across the undergraduate, post-graduate, and career development levels to meet the needs of students. This roundtable session will engage the SABER community in an exploration of curriculum reform and DEIJ, with the intent to identify areas for further action.

Ideas and Desired Input: An overview of curricular reform will be presented followed by an interactive discussion of: 1) How does our current approach to course and curricular design act to screen out diverse future life scientists and practitioners? 2) What would a socioeconomically equitable life science curriculum look like? 3) What steps are needed to implement these changes?

Participatory Component: Participants will have the opportunity to discuss questions in small groups and offer input verbally, visually, and digitally via anonymous polls. We will provide handouts with scaffolded prompts. Members of the D&I Committee will facilitate discussions and gather ideas for action and implementation from participants interested in culturally-responsive pedagogy and curricular reform.

Contribution: To contribute to SABER’s DEIJ goals, all ideas and input will be analyzed and reported to the SABER membership for possible future action. We are interested in identifying areas for collective action and/or proposal submission related to curricular reform within STEM education.

Roundtable 8: The Interplay of Social Capital and Field Education: Influences on Student Emotional Outcomes
Annie E Meeder (University of Colorado Boulder)*; Lisa Corwin (University of Colorado Boulder)

Abstract:
Field courses offer a unique pedagogical environment where social capital—defined as the network of relationships within a particular society or institution—has the potential to significantly influence student experience. High levels of social capital in students can support academic success (Brouwer et al. 2016), but recent literature has found that underserved student groups
may not have access to specific types of social capital supports (Mishra 2020). While field
courses have been shown to be a transformative experience in learning, aspirations, and social
networks (Shortlidge 2021), underserved students may not have the same outcomes as their
majority peers (Bowser et al. 2012) and could encounter financial, physical, social, or cultural
obstacles during field work (Morales et al. 2020). This research aims to understand the role of
social capital within field education and its potential to transform student engagement, learning
orientation, and sense of belonging in minority groups. We hypothesize that students' starting
social capital significantly shapes their experience and that field courses can both enhance and
shift the dynamics of this capital. Utilizing a mixed-methods approach (Warfa 2016), we propose
to examine how initial levels of social capital, as gauged by parental involvement, peer
interactions, and relationships with faculty, influence the emotional outcomes of field education.
We are particularly interested in the effect of perceived social capital on students before and
after field courses, and how this perception correlates with emotional outcomes, such as a
sense of belonging and place. For the roundtable, I seek feedback on the research design,
particularly the operationalization of social capital in the context of field education. The first part
of the session will involve a structured dialogue on the potential of field courses to change
student aspirations and improve social capital. A handout with key research questions and data
collection modalities will guide the discussion and provide a framework for feedback. The goal
of this research is to enhance our understanding of how social capital influences the emotional
outcomes of field courses and to further guide the design of inclusive field experiences that
promote equity in educational outcomes. By exploring the transformative potential of field
courses, we aim to support the development of scientific identity and retention in biology among
a diverse student population.

Mishra, S. 2020. Social networks, social capital, social support & academic success in higher
education
Shortlidge, E. 2021
A resource for understanding & evaluating outcomes of undergraduate field experiences
Brouwer, J 2016. The impact of social capital on self-efficacy & study success among students
Bowser, G. 2012. The color of climate
Morales, N 2020. Promoting inclusion in ecological field experiences
Warfa, A. R. M. 2016. Mixed-methods design in biology education research

Roundtable 9: Strategies for Building a DBER Cluster at a University
Peggy Brickman (University of Georgia)*; Paula P. Lemons (University of Georgia); Erin Dolan
(University of Georgia); Tessa C Andrews (University of Georgia)

Abstract:
One gap in knowledge in biology education research is how to build a cluster of discipline-based
education researchers at an institution. Many discipline-based education researchers (DBERs)
desire to serve as change agents for STEM education at their institutions, yet the lift is too
heavy without colleagues. Institutions with clusters of DBERs benefit from these scholars’ high
quality research, instruction, and mentorship, and from their knowledge of educational and
organizational systems that make them excellent leaders (e.g., undergraduate and graduate
coordinators, faculty senate chairs, search committee chairs, department chairs, deans). This research-in-progress aims to uncover the key factors and principles that led the University of Georgia to develop into a hub for DBER. Given that DBER has only developed over the last few decades, this question remains unaddressed. We seek to engage with participants who work at other DBER hubs and participants who seek insight about how to build a DBER hub at their own institution.

Universities develop centers to support academic excellence through enhanced research exchange and mentorship among members. As the reputation of the center grows, recruitment of students and additional faculty increases. Synergistic opportunities for collaboration and development lead to greater productivity and success, which can feedback to enhance the reputation of the center. This was definitely not the original goal of our university in creating early DBER positions, nor were they particularly supportive of our efforts to develop our Scientists Engaged in Education Research (SEER) Center. However, we believe that our experience could help inform and support faculty efforts at other universities to develop a DBER hub or center.

In this roundtable discussion, we will describe the stages of development of our SEER Center, including "behind the scenes" descriptions of hurdles we overcame and strategies that we used to support our members. We will outline opportunities that we used to leverage our successes and examples of mechanisms we used to support our members in the broader community.

We will ask participants to reflect on levers they could use at their institutions to build a larger community of DBER scholars and to interrogate our experience with questions that help us uncover critical factors that enabled growth and thriving of DBER at UGA.

This roundtable will be relevant to SABER attendees who want to be change agents at their institutions, and the roundtable outcomes can serve as information about the value of further investigation of the UGA story.

**Roundtable 10: Investigating a framework integrating ideas from inclusive teaching and classroom communities of science practice for supporting students’ sense of science belonging in a large-enrollment introductory biology class**

Susan Hester (University of Arizona)*; Lisa Rezende (University of Arizona)*; Corin Gray (University of Arizona)*

Abstract:
Study Background:
Large introductory science courses present an opportunity for supporting the persistence of a wider population of students in science. Contributing to students’ sense of belonging in STEM may be a way to influence persistence (e.g., Hernandez et al., 2013, Graham et al., 2013). We are redesigning a large-enrollment (200-400+) introductory biology course at an R1, land-grant Hispanic-Serving Institution. We are interested in identifying (1) curricular design elements and (2) models for LA training and integration into the classroom that foster students’ sense of
science belonging. Our focus is on designing for students’ cognitive and social engagement in science practices as part of a supportive community environment.

Research Ideas:
We plan to investigate the impact of curricular design and models for LA training and integration on students’ sense of science belonging. Our design principles and proposed analytical framework integrate ideas from theories of inclusive teaching (Dewsbury and Brame, 2019) and classroom communities of science practice (Ford 2015). We predict (1) integrating elements of science practice will provide opportunities for meaningful science-centered interactions between students, and between students and the instructional team (instructor, TAs, LAs); and (2) integration of LAs as co-collaborators will support an inclusive science community within the classroom, and ultimately students’ sense of science belonging.

Desired Feedback:
We are seeking feedback on our design principles and emerging research framework integrating theories of inclusive teaching (Dewsbury and Brame, 2019) and classroom communities of science practice (Ford 2015).

Participatory Component:
Our one-page handout will share a visual representation of our proposed framework with predicted connections/alignment between the elements of the model and features of curriculum design and LA integration into the class, and research tools (e.g., surveys) we may use to address those connections. We will present a set of guiding questions to solicit feedback on the proposed investigation.

Contribution:
We seek to contribute to the community’s understanding of how particular types of active-learning structures and activities, including models of LA training and integration, can best support factors likely to contribute to students’ science trajectories. Linking elements of course design to these outcomes has broad implications for the biology education community.

Roundtable 11: Navigating the Minefield: Impact and Implications of Anti-DEI Measures
Erika L Williams (North Carolina Agricultural and Technical State University); Nicole L Scheuermann (Northern Illinois University)*; Brock Couch (Loyola University, Maryland); Justine S Liepkalns (Colorado State University); Bailey M Von der Mehden (University of Tennessee, Knoxville); Clark R Coffman (Iowa State University); Ariel J Chasen (UT Austin); Teri Balser (University of Calgary); Dawn Foster-Hartnett (University of Minnesota)

Abstract:
BACKGROUND: Diversity is important for student learning and innovation in the workforce (Gurin et al., 2002; Hong & Page, 2004), but this requires classroom spaces that enact components of diversity, equity, inclusion, and social justice (DEIJ) to support students (Handelsman et al., 2022). Instructors value teaching these “controversial” topics (Beatty et al., 2023), but nearly 300 “anti-DEI” laws have been proposed, with at least 25 states enacting such
measures (Nataonson et al., 2022; Martinez-Alvarado & Perez, 2023). This poses professional risks for educators engaged in DEIJ work, such as SABER members. Understanding the needs of SABER members in navigating this landscape is essential, but societies cannot make assumptions about members’ needs (Madzima & MacIntosh, 2021). Therefore, the SABER Diversity and Inclusion (D&I) Committee plans to hold a roundtable session to gather members’ input in a supportive environment.

Research & Feedback: The D&I Committee will host a roundtable at the 2024 SABER annual meeting to understand the needs of members and attendees involved in DEIJ work amidst legal changes. We aim to uncover: 1) the impact of anti-DEIJ laws on teaching and research; 2) SABER’s role in advocating for positive legislation; 3) how SABER can support individuals in DEIJ work; 4) how to support change within home institutions; and 5) possible other insights on anti-DEIJ legislation from instructors’ perspectives.

Participation: The roundtable will consist of an open dialogue between the SABER D&I committee and the SABER community to gather feedback on SABER’s role in advocating for DEIJ, in alignment with our Diversity Statement. The committee will engage both in-person and virtual attendees concurrently, through facilitated discussion. In-person attendees will receive a handout with guiding questions, from which we hope to collect anonymous answers. We also plan to post large Post-it notes on which attendees can collectively write or draw. Virtual attendees will have a similar opportunity to provide anonymous feedback via websites like Menti or Google Jamboard. Attendees will receive handouts of resources to understand and navigate anti-DEI legislation.

Contribution: Collected, de-identified data will used to inform SABER leadership of membership needs regarding DEIJ legislation. The ideas and suggestions from this roundtable will be utilized by the D&I committee to help design supports for members that would help resist anti-DEIJ measures.

**Roundtable 12: "The Intersection of Chance Events, Chronic Illness, and Graduate Student Career Trajectories"
Hope Ferguson (University of Tennessee)*

Abstract:
Study Background: Chance events—the unplanned and unpredictable—significantly shape the career intentions of life science graduate students (authors). While these events were initially appraised as disruptions or challenges, participants reappraised these events into personal and professional growth opportunities. However, we noted that those who changed their career intentions due to chance events often acknowledged mental health challenges while in their programs (authors). Given that 11% of graduate students report disabilities (NSF, 2023) this implies that graduate students with chronic illnesses or disabilities may be more likely to encounter chance events affecting their career intentions, increasing challenges towards self-advocacy, stigma, and lower expectations (Gin et al., 2020). In light of this, how do graduate students with chronic illnesses appraise chance events in their academic programs?
Description of research ideas: I aim to conduct interviews exploring the interplay between chance events, chronic illness, and their influence on life science graduate student careers. I prioritize creating a supportive environment where participants will feel comfortable sharing their perspectives. Therefore, it's crucial to honor their experiences and analyze data with sensitivity. At SABER, I seek feedback from the attendees to provide insights on their experiences or graduate student experiences with chronic illnesses, the strategies to support them, and how chance events may impact them. I also seek advice on accurately representing the voices of participants’ with chronic illnesses in data analysis.

Participatory component: During the roundtable, I'll encourage participation by inviting attendees to share personal experiences or insights with chronic illnesses and chance events, either openly or anonymously. We'll engage in a brainstorming session focusing on common challenges faced by graduate students with chronic illnesses in academia. Participants will receive a handout outlining the study's background, significance, and guiding questions for the session.

Contributions: This research highlights the need for research on coping strategies, decision making processes, and resource use for graduate students with chronic illnesses. This work will foster discussions with educators and advisors to gain a better understanding of their students’ experiences and inform approaches to mentorship that are unique for their students’ needs.

Roundtable 13: Investigating how field courses held at field stations effect self-efficacy and sense of belonging in biology undergraduate students
Zachary Schwartz (University of Colorado, Boulder)*; Lisa A Corwin (University of Colorado Boulder)

Abstract:
Undergraduate field courses provide a unique opportunity for place-based learning. Moreover, residential field courses, field courses in which students live at/near a field sites, provide an immersive educational and social experience. Previous literature has demonstrated that there are several benefits of residential undergraduate field experiences that enhance learning outcomes, including improved content knowledge (Hannula et al., 2019), higher levels of scientific design and skills (Shaulskiy et al., 2022), and development of deep connections with peers and professionals (Esparza and Smith, 2023). Shaulskiy et al. (2022) discusses how residential field courses showed improved scientific literacy, which was a result of an overall greater sense of belonging and learning orientation. However, it is not well understood if this was a product of the field station itself. My research will investigate how residential field courses at field stations affect self-efficacy and a sense of belonging for undergraduate students. We will be using van der Hoeven Kraft’s (van der Hoeven Kraft et al., 2011) Affective Domain framework to examine this. Utilizing the Affective Domain framework will enable us to explore how the connection to the environment created by learning at a field station influences self-efficacy and a sense of belonging. We will employ a mixed-methods approach to better understand the experiences of the participants and capture quantitative differences that may be
attributed to the residential field course (Warfa, 2016). I am soliciting feedback from the roundtable to help deliberate on the merits of the current research proposal, any advice the group may have, and the unforeseen challenges we may face. I will spend the first few minutes asking the group to do a free write on the benefits and challenges for undergraduate students to participate in a residential field course. To guide our discussion, I will have printout rubrics with categories that cover the research questions, modality for data collection, and topics I want to discuss with the roundtable. This will also act as a place for participants to provide feedback. The aim of the research project is to better understand how residential field courses affect undergraduate ecology research self-efficacy and sense of belonging, which are both important psychosocial outcomes that promote scientific self-identity (particularly in ecology) and retention in biology (Shaulskiy et al., 2022).

Roundtable 14: Importance of Place
Sheritta Fagbodun (Tuskegee University)*; Paula E Adams (Auburn University); Robin Costello (Auburn University); Abby Drake (Cornell University); Ryan D.P. Dunk (Auburn University); Sharday N Ewell (University of Mississippi); Dawn Foster-Hartnett (University of Minnesota); Marcos García-Ojeda (University of California, Merced); Kristen Hobbs (Kansas State University); Kristina K Prescott (University of Minnesota, Twin Cities); Kent Reed (University of Minnesota); LeCia Robinson (Tuskegee University); Preston Robinson (Tuskegee University); Archana Sharma (Tuskegee University); Deena Wassenberg (University of Minnesota); Sehoya Cotner (University of Bergen)

Abstract:
In July 2023, members of the Equity and Diversity in Undergraduate STEM network and the Tuskegee University Howard Hughes Medical Institute Inclusive Excellence 3 initiative met to engage in a professionally facilitated workshop centered on anti-biased, anti-racist STEM education. Key in the planning of this workshop was site selection, in that members chose to have these discussions at Tuskegee University, a Historically Black College and University (HBCU) in Alabama steeped in a history entangled with America’s legacy of racism, slavery, and segregation. A theme that emerged repeatedly throughout the workshop was how much location matters, and how the conversations we had would have been far less meaningful if they had been attempted elsewhere. At this roundtable we will discuss this workshop—its rationale, participants, key features, and outcomes—with a specific emphasis on the importance of place in these discussions.

We expect participants to engage in discussion centered around
(1) Core elements of the workshop
(2) How site selection for diversity, equity, and inclusion (DEIJA) discussions can either prohibit or promote inclusivity
(3) How to make future DEIJA discussions inclusive

To achieve (1), we will lead participants in one activity, in which we share a handout that will encourage consideration of the concepts of the “Center” and “The Borderlands,” following the framing of Gloria Anzaldúa (Anzaldúa, 1987). We will also share our experience with a
“positioning” exercise, in which we will place our institutions on a six-point continuum from 1 (an Exclusionary Institution = White culture where differences are seen as deficits and threats) to 6 (a Fully Inclusive Anti-Racist Multicultural Organization). Both activities can be taken to the participants’ home institutions.

We will then take ten minutes to summarize our experience with the workshop at Tuskegee. This will include an overview of activities (Fagbodun), a summary from post-workshop input from participants on what they gained (Costello), and take-home messages, with one-minute contributions from the remaining presenters. Then, we will have a more open discussion of items (2) and (3), above. Our plan, depending on the size of the group, is to break into groups with assigned questions to discuss, and then bring back to the larger group. Ultimately, we hope to encourage our colleagues leading similar discussions to seriously consider how to make future DEIJA discussions truly inclusive.
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