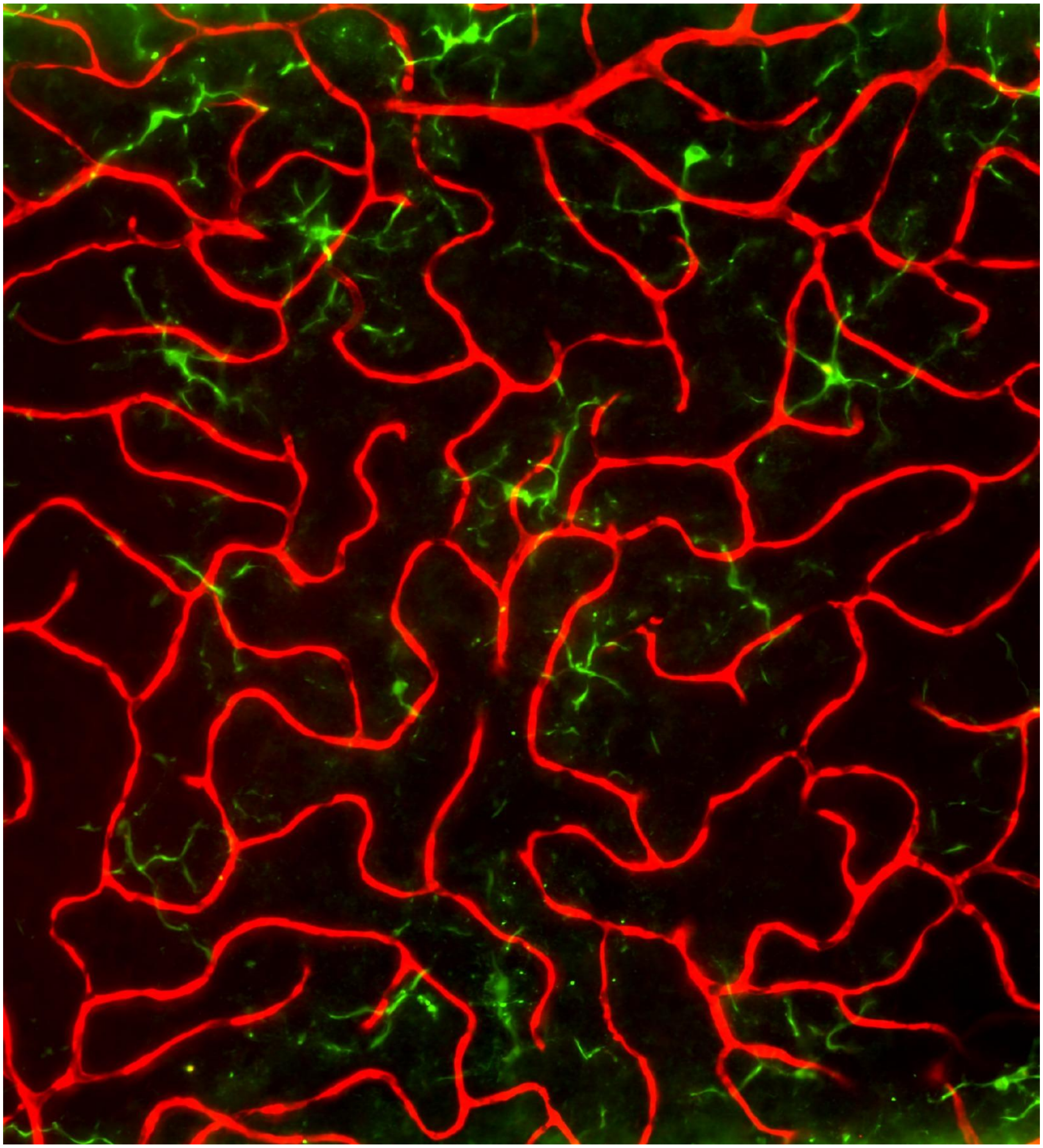
Bioscene
Journal of College Biology Teaching



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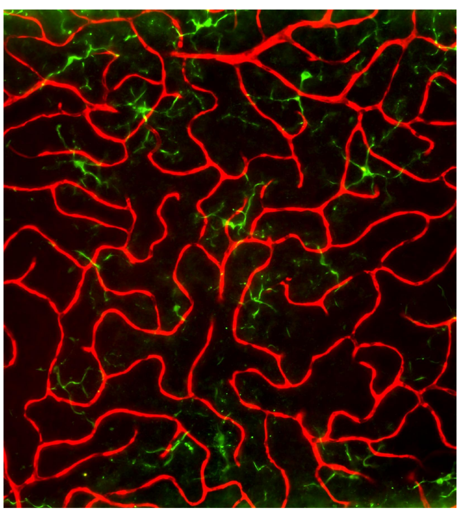

Cover image:
Wholemount retina in which the vasculature has been labeled with tight junction marker occludin (red) and microglial cells have been labeled for IBA1 (green).

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A Publication of the Association of College and University Biology Educators

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Members of ACUBE share ideas and address the unique challenges of balancing teaching, research, advising, administration, and service.

We are a supporting and mentoring community that provides professional development opportunities to:

- develop and recognize excellence in teaching;
- incubate new and innovative teaching ideas;
- involve student research in the biology curriculum;
- advise and mentor students in and out of the classroom;
- enhance scholarship through our international, peer-reviewed journal, *Bioscene*.

70th Meeting at Broward College, October 2026
Local Arrangements Chair: Jonelle Orridge
https://www.acube.org/Annual.php

Articles

Student-authored websites of biologists marginalized in history are associated with students' awareness of equity, diversity, and inclusion.

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Abstract

As a discipline, biology has historically had low diversity in representation among its members. To combat this, we have implemented a team website assignment in our biology capstone course that prompted students to research a biologist who was marginalized during their career. The broader purpose of this non-traditional capstone course, which focuses on the history and theory of biology, is for students to integrate their biology education with other ideas and concepts they have learned on our liberal arts and sciences campus, along with their understanding of the world. The objective of the website assignment is to provide students with the opportunity to explore a scientist who made important contributions to biology, but who was not broadly recognized for these contributions at the time. Beyond spotlighting the biologist, a broader assignment goal is to develop students' awareness and understanding of equity, diversity, and inclusion (EDI). Twelve students from the Winter 2022 class were recruited and interviewed to assess whether the assignment achieved its broader goal. Our findings suggest that students responded positively to the assignment and that their understanding of EDI developed. Given the recent attacks on EDI, it is even more important that we intentionally integrate it into our classrooms.

Keywords: capstone, diversity, equity, history of biology, inclusion, marginalization

Introduction

In recent years, calls to action for Reconciliation, Decolonization, and Equity, Diversity, and Inclusion (EDI) for historically underrepresented, marginalized, and excluded groups have been amplified. While universities should be diverse, equitable, and inclusive in their training, historically, they have not been (Barber et al., 2020). To dismantle systemic racism in academia and biology, more specifically, we need to transform policies and practices, including in our classrooms. This need is becoming even more critical as recent EDI progress is under increasing threat (Conyers & Wright Fields, 2025).

Towards centering EDI in our classrooms, the University of Alberta, Augustana Faculty's biology capstone course, History and Theory of Biology (N. C. Haave, 2017), assigns a team project that asks students to create a website that provides a biography of a biologist who has been marginalized in the history of biology. This paper considers how the assignment is structured, the prompts provided to students, and how it is scaffolded and graded. In addition, we present data that indicate that the assignment is well received by students and impacts their awareness of EDI in biology.

This website assignment is a modification of the Scientist Spotlight (SS) assignment (Aranda et al., 2021a; Brandt et al., 2020; Metzger et al., 2023; Schinske et al., 2016; Yonas et al., 2020). The SS assignment was first implemented to have students find scientists to whom they could relate (Schinske et al., 2016), presenting a variety of scientists to students. Initially, these SSs were instructor-driven with instructor-provided biography resources for students to read and reflective question prompts to engage the students with the scientist: Simply presenting diverse scientists to students in class did not impact the ability of students to identify with scientists and the doing of science without the metacognitive prompts (Schinske et al., 2016). The objective of this type of assignment was to enable students to see themselves as potential scientists regardless of their background. These types of assignments may also engage students in the social context of science, which has been suggested to help students see the relevance of science and thus produce greater engagement in students with the science concepts they are learning (Chamany et al., 2008): If it is relevant to students' lives, then they may pay closer attention to the material and engage with the material at a greater depth resulting in improved student learning outcomes.

Our website assignment is a student-driven SS, which enables students to choose their scientists. Having students choose their subject provides scientists that are more reflective of students' current self-conception and thus may increase the ability of students to see themselves as having a place in the doing of science (Aranda et al., 2021a). Our assignment asks students to research a historical biologist who was marginalized. The learning objectives of the assignment are to: 1) raise students' awareness that EDI has been an issue in the doing of biology throughout its history, and for them to reflect on whether it is still an issue today; 2) provide a social context for the biology they have been learning; and 3) increase students' ability to see themselves as potential scientists. This assignment is also an active way to honor ACUBE's commitment to EDI (Association of College and University Biology Educators, n.d.). Publishing the website online encourages students to ensure their research is evidence-based and combats the misinformation rampant on the Internet. This increases students' engagement with a project (N. Haave, 2012).

Methods

The assignment was implemented and assessed in a senior course, History and Theory of Biology, which is the capstone course for the Augustana Biology degree program. This capstone is limited to students in the 4th year of their biology major. It uses an overview of the biological sciences' historical progression and associated development with prevailing philosophical, social, and cultural contexts to prompt students' reflection on their biology degree program. Prerequisites for the course include a 3rd-year developmental biology course and a 3rd-year biodiversity course. Two introductory biology courses and a 2nd-year genetics course are prerequisites to the two junior prerequisite courses. The weighting of the website assignment was 25% of students' final course grade, with the other 75% contributed by a midterm exam (20%), a final exam (or a learning portfolio assignment in some years) (35%), and in-class team assignments (20%). The structure of the classroom is a modification of team-based learning (TBL) in which students are assigned to instructor-designed teams such that there is inter-team homogeneity but intra-team heterogeneity (Michaelsen & Sweet, 2011). Students were assigned a reading for almost every class (the class met twice a week for 90 minutes for an 11-week semester during the term). Classes began with students discussing among their teammates the thesis of the assigned reading and how it was connected to what had been read for, and discussed in prior classes, and to their own lived experience. The bulk of a class meeting (approximately two-thirds) consisted of discussion among teams with question prompts from the instructor as required. Occasionally (approximately four times during the term), teams were required to produce a product (e.g., a short presentation, answers to questions shared with the entire class) that was assessed by the instructor. For the biologist website assignment, the same teams worked together to research and produce their websites, which were due during the last week of class with two check-ins earlier in the term: 1) The name of the chosen biologist and a possible thesis for their marginalization (due at midterm); 2) A brief point-form outline of their website (due three weeks before the end of term). The check-ins were not graded but rather were go/no-go assessments by the instructor with feedback as appropriate.

The instructions for the assignment were included in the course syllabus with the following wording:

"The overarching purpose of this course is for you to be able to integrate your biology education with the other ideas and concepts that you have learned in the sciences, social sciences, humanities, and fine arts, along with your broader understanding of the world. As you proceed in this class, you may observe that there are certain voices that we hear from often, and others we do not. It is important to ask: “Who are we missing?”. While a focus on equity, diversity, and inclusion may be more prioritized in science now, historically, that was not the case. There are many scientists who we do not know about today because they were treated as insignificant or peripheral (i.e., marginalized) based on factors that were not related to their scientific contributions. The objective of this assignment is to provide you with the opportunity to explore a scientist who made important contributions to biology, but who was not broadly recognized for these contributions at the time. You will use your core academic skills as a communicator, researcher, collaborator, and critical thinker to create a website on a biologist who was historically marginalized and who you think should be spotlighted.

Each team will research a biologist in history who experienced marginalization during their academic career.

Once you have identified a biologist, you will create a website that showcases the biologist. To do this, you need to start by discussing their contribution to biology and why it should be considered significant. How did the biologist advance our understanding of biology?

Recognizing the significance of their contributions to biology, you then need to solve the ‘mystery’ of why the biologist was marginalized. Why don't we know more about this biologist? In this second part, you need to uncover/explain/reveal why their significant contribution(s) was/were hidden (Until now...). You should also explain how they were marginalized – what actions were taken to silence/diminish their contributions? Was this conscious or unconscious? Why do you think that?

When gathering and citing your information, ensure that you use only peer-reviewed sources or that you have gone back to the original source (e.g., the marginalized biologist's original published manuscripts or letters). Beware of information that does not cite its sources. You do not want to rely on someone who is making material available on the internet that they have simply made up!

The rubric for the final assignment will be available on our Learning Management System.”

The assignment rubric is depicted in Figure 1. The class teams of 4-6 students each jointly produced their website, with the same grade assigned to all members of the team. Social loafing (Perron, 2011) was discouraged by having students evaluate their teammates' contribution to the assignment by assigning a % participation mark to each other (excluding themselves), which was used by the instructor as a multiplier of the team mark to calculate individual marks. Students were given enough percentage points to give each of their teammates 100%, such that if one teammate went above and beyond 100% (e.g., 110%), those extra points (e.g., 10%) would have to come from other teammates’ participation marks. Two peer evaluations were done during the term: a formative evaluation at midterm and a summative evaluation at the end of the term. The formative evaluation allowed teammates to provide anonymous feedback to one another, to incentivize students to improve their team contributions for the remainder of the class, improving their chances of a better grade by the time of the summative evaluation. Only the summative evaluation influenced students’ final grades.

In the summer of 2022, two undergraduate students recruited and interviewed 12 students from the Winter 2022 cohort of Augustana’s biology capstone course to determine their responses to the website assignment. Semi-structured interviews were conducted one-on-one over Zoom, recorded, transcribed, and thematically analyzed using NVivo after the data had been anonymized. Two hours were scheduled for each interview, but the interviews never went that long; an interview was typically between 30 to 60 minutes in length. Question prompts used in the interview are listed in Table 1. This study was approved by our institution’s REB (protocol #00117579). We have done light editing for readability where appropriate (i.e., removed “likes” where they interrupted the flow of the quote).

Figure 1. Rubric used to grade the website assignment of a biologist historically marginalized. This rubric was made available to students on the university's learning management system.

	Exemplary (4)	Proficient (3)	Basic (2)	Minimal (1)	Unacceptable (0)	POINTS (4)	SCORE
Effectiveness of Content	Includes all material needed to gain a comfortable understanding of the topic. Clear & concise. Logical progression of ideas. Accurate & complete.	Includes most material needed to gain a comfortable understanding of the material but is lacking 1 or 2 key elements. Logical progression of ideas. Unnecessary length/detail or some content missing or superficial.	Website is missing more than 2 key elements. Vague in conveying point. No sense of purpose. Information shows some understanding of topic.	Website is lacking several key elements and has inaccuracies. Lacks a clear point. No logical sequence of information. Limited understanding of topic. Not all accurate.	Website is incomplete. Content present is misleading.		**/20**
Research	Sources cover the desired topic without being extraneous. No errors in citations.	Sources are adequate and show evidence of careful research. Some errors in citations.	Sources indicate some research but not always relevant. Citations errors exist.	Sources show little evidence of adequate research. Too many or too few citations with many errors.	Sources are insufficient. Research is cursory and inadequate. Citations are generally incorrect.		**/20**
Organization	Information is organized in a clear logical way. All parts are fully completed and support the theme/content of the website. All links within the website and to other places on the web work perfectly.	Most information is organized in a clear logical way. One webpage or item of information seems out of place. All parts are completed partially and support the theme/content of the website. Most links within the website and to other places on the web work perfectly.	Some information is logically sequenced. An occasional webpage or item of information seems out of place. Some webpages do not support the theme/content. Some links within the website and to other places on the web work perfectly.	Website is missing several parts or does not support the theme/content. Few links within the website and to other places on the web work.	There is no apparent logical organization.		**/15**
Graphics & text	Layout is visually appealing & supports overall message. Text is easy to read: point size varies appropriately for headings & text. Appropriate use of graphics.	Layout is pleasant. Graphical theme is appropriate. Font is sometimes difficult or distracting to read.	Layout appears cluttered or busy. Graphical theme is distracting. Font is often difficult to read: inappropriate use of bold, italics or underline.	Layout is cluttered, confusing. Graphical theme is very distracting. Large gaps of white space. Text is very difficult to read. Inappropriate use of colour contrast, etc.	Graphical & font design makes reading & understanding difficult.		**/20**
Originality	Website shows considerable originality & inventiveness. The content & ideas are presented in a unique & interesting way.	Website shows some originality & inventiveness. The content & ideas are presented in an interesting way.	Website shows an attempt at originality & inventiveness on 1 or 2 webpages.	Website recycles other people's ideas &/or graphics & shows very little attempt at original thinking.	There is nothing original.		**/10**
Syntax & Mechanics	No spelling, punctuation, or grammatical errors.	Little or no editing required for spelling/grammar.	Errors exist in text.	Many errors exist in text. Spelling, punctuation, capitalization, usage, and grammar errors are repetitive and distracting.	Unintelligible.		**/5**
Presentation	Adds relevant information besides what is on the website. Shows interest and enthusiasm. Speaks with clear voice with appropriate volume. Does not use verbal fillers (umm, ahh, so, like…).	Adds some information besides what is on the website. Shows general interest in topic. Speaks clearly most of the time. Volume is adequate. Rarely uses verbal fillers (not distracting).	Adds little information besides what is on the website. Shows little enthusiasm/interest. Needs to speak a little clearer. Needs to speak a little louder/softer. Sometimes uses verbal fillers.	Does not add anything relevant besides what is on the website. Does not show interest in presentation. Can't understand the speaker. Volume is not appropriate (too loud/soft). Constantly uses verbal fillers.	Simply read the slide or read their text rather than speaking to audience. Mispronounced names/words.		**/10**
TOTAL							**/100**
COMMENTS:							

Table 1. Question prompts used during the study interviews.

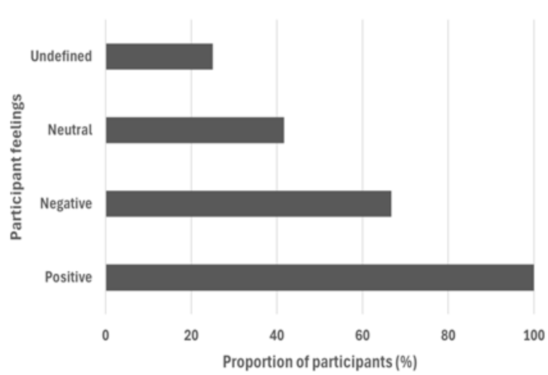
How did the marginalized biologist assignment make you feel? What types of emotions did you feel in response to this assignment, during and after its completion? Please explain your answer. At what point in the process did you experience these emotions?
Can you please compare the marginalized biologist assignment with other kinds of assignments you have completed during your degree?
What did you learn from completing the marginalized biologist assignment? [learning outcomes]
How did the marginalized biologist assignment influence the way you think about equity, diversity, and inclusion (EDI) in the context of our society in general?
How do you think the marginalized biologist assignment affected your other courses, either those you were taking at the same time as AUBIO 411* or after?
How do you think the marginalized biologist assignment would have affected your courses differently if you had completed it in a different year, earlier in your degree program?
How do you think completing the marginalized biologist assignment in a different year of your undergraduate program would have affected your thinking about EDI?
Did the marginalized biologist assignment teach you anything that has stuck with you since the completion of *AUBIO 411? Anything that you are still thinking about today? If yes, can you please elaborate on what elements you are still using?
How would you improve the marginalized biologist assignment?
Is there anything else you would like to share with me?

* AUBIO 411 is the course code for the capstone course – History and Theory of Biology.

Results

The demographics of the participants are indicated in Table 2. Briefly, the ages of the participants ranged from 21-23 years and were split approximately evenly between male and female, with one participant identifying as non-binary. A little less than half the class self-identified as belonging to a community that was marginalized (e.g., LGBTQIA+, Indigenous). Note that only one of the five females in the study self-identified as being in a marginalized (female) group.

Figure 2. Feelings elicited in students by the website assignment of a biologist marginalized in history.



As shown in Figure 2, the website assignment elicited a range of emotions among students. While all participants reported positive feelings, a majority (but not all) still experienced negative emotions. Nine of the students specifically stated that the assignment was interesting.

Table 2
Demographics of interviewed participants (n=12).

Participant characteristic		Percentage
Age	21	33.3
	22	16.7
	23	50.0
Major	BSc Biology	83.3
	BSc/BEd	8.3
	BSc Double Major	8.3
Year level	3rd year	8.3
	4th year	58.3
	5th year	33.3
Gender	Female	41.7
	Male	50.0
	Non-Binary	8.3
Self-identify with a marginalized group	LGBTQIA+	16.7
	Indigenous	8.3
	Female	8.3
	Yes (but not specified)	8.3
	Not Applicable	58.3

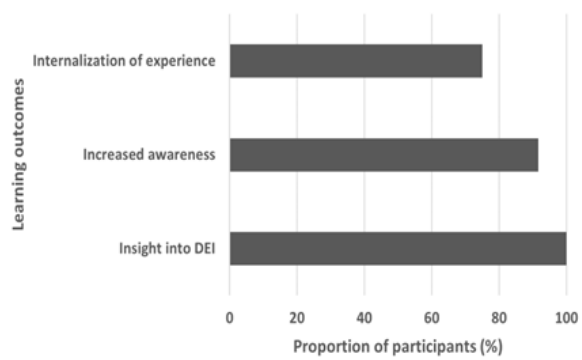
Some examples of the emotional responses that the assignment elicited in students:

“Kind of sad in a way to hear about all of these things that happen and still happen.” - MDA 836

“Any time that you are dealing with discrimination humans have faced in their life of course that makes you feel… generally I think confronting that actual feeling is important to, just kind of learning how you can prevent that uncomfortable feeling happening to anyone else in the future.” - MDA 418

All students indicated that they gained insight into EDI because of the assignment, with a majority of students also demonstrating that they had internalized the experience and increased their awareness of EDI in biology (Figure 3).

Figure 3. Learning outcomes resulting from the website assignment of a biologist marginalized in history.



Some sample student comments illustrating what students felt they learned from the assignment:

“I thought it was a really eye-opening experience for me, at least in terms of EDI.” – MDA 308

“The class definitely gave me a lot more background and just furthered my understanding of, you know why those [EDI] programs are important and historically how different groups have been excluded from biology.” - MDA 906

“I thought it was a very fulfilling assignment, and it kind of gave me a very new perspective on science as a whole, and just scientists being marginalized in the past and presently actually.” - MDA 720

Comments during the interviews indicated that student development occurred because of the assignment:

“It [the assignment] broadened my horizons and made me understand how the challenges and problems other people go through that not necessarily everyone faces. And, I don’t know, it made me feel a little more empathetic towards you know, minority groups.” - MDA 739

“Being able to identify with the people I was or the person that I was looking into and the historical context around that. … Oh wow, this is something that somebody did and could have affected me … .” - MDA 240

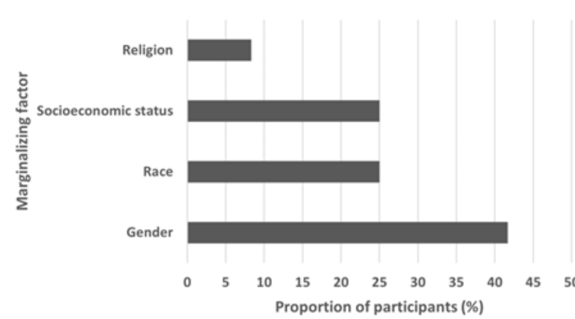
“I think there was a bit more insight and reflection that occurred with this assignment.” - MDA 234

The factors contributing to marginalization, identified by students because of the assignment, included socioeconomic status, religion, race, and gender (Figure 4). Gender was the most common factor identified. Since 2021, when this website assignment was first implemented, until 2024, the majority of biologists researched by students have been females (N. Haave & McIntosh, n.d.). When queried, the students replied that their research simply located more resources about females than about other genders.

Some students connected with their biologists, understanding their struggles and seeing themselves in the experiences and lives of biologists historically marginalized:

“I did sort of feel, I guess a sense of pride in

Figure 4. Contributing factors to marginalization identified by students while completing the website assignment of a biologist marginalized in history.



what I was doing in terms of being able to identify with the people I was or the person that I was looking into and the historical context around that." - MDA 240

"So [they] are definitely an inspiration and when I'm feeling discouraged or I don't know what to do, I actually think of [them] because [they] faced so much adversity and were able to overcome it." - MDA 906

Some students during their interview indicated that they thought there were longer-term impacts on their learning because of the assignment:

"I still think of the biologist that we chose, [anonymized biologist], actually on a pretty regular basis. [They] were really, a really prolific researcher and accomplished a lot with very limited resources. So [they] are definitely an inspiration and when I'm feeling discouraged or like I don't know what to do, I actually think of [them] because [they] faced so much adversity and were able to overcome it. So yeah, I still think of I guess not only our biologists but a lot of the other biologists that the other groups focused on because they did prove that it's possible to overcome challenges and to face adversity. …" MDA 906

Seven students (58% of the respondents) specifically stated that they thought that the construction of a website investigating a biologist who experienced marginalization was a good project to capstone their degree:

"It does just tie everything together … I think it's a really important way to end a biology degree." MDA 816

"So I think it was good to have it as an ending to your science degree rather than a beginning to your science degree because it really makes you think about the community after you've learned all about it." MDA 836

"I think the marginalized biologist assignment actually came at a good time. I don't know if I would have wanted to complete it earlier in my degree. I think the courses that I had taken prior to the capstone class gave you the proper skills to complete the class and the marginalized biologist assignment." MDA 906

Discussion

Our website assignment, which researched biologists who have been historically marginalized, was received positively by students and increased their awareness of EDI in biology. In addition, students became aware of the different factors contributing to marginalization that occurred in the history of biology. Student comments suggested that they connected with their biologists and may have developed a greater sense of empathy for those who find themselves marginalized. Inequity still exists today in science (Bernard & Cooperdock, 2018; Johnson, 2007; Moore, 2001; Tanner, 2009) and what was gratifying to see is that this history assignment raised students' awareness of the necessity to address EDI today. This website assignment provides instructors a structure to raise EDI issues directly in the classroom by introducing students to the diversity of people working in biology, which has been reported to increase students' awareness of EDI (Kansman et al., 2022; Killpack & Melón, 2016). This website assignment, as a rendition of student-authored scientist spotlights (Aranda et al., 2021b) is one approach that instructors can implement to address the learning environment rather than fixing the student, to increase the diversity of participation in STEM (Thoman et al., 2021).

The student comments in this study reflected issues raised in our classroom conversations about their researched biologists who were historically marginalized. Students commented that discrimination based on gender and race is still evident in the sciences, but perhaps not as explicitly as it once was, but that the marginalization of a biologist's work can continue after death. Students' websites (N. Haave & McIntosh, n.d.) indicate that marginalization is relative and intertwined with privilege in many instances: Biologists are humans, and humans are influenced by social factors. Students' research also identified the intersectionality of the issue: Marginalization seemed to be magnified if a person fits into more than one marginalized group (e.g., Black Female). Students also noticed that marginalization could look very different from case to case and that it is difficult to know if a biologist's relative obscurity in the history of biology is a direct result of their marginalization.

Students’ websites also document many socioeconomic barriers that were systemic, as exemplified by the policies of institutes and professional organizations. Students observed that their own biases influenced how they ranked and discussed biologists who have been marginalized in history.

Most biologists who were researched for this website assignment were females. When we raised this focus with our students, they replied that they simply found more resources regarding females in biology. We wonder if this is a result of the work of feminist scholarship that came to prominence in the 1970s (Allegrini, 2015). Investigations into the marginalization of people of color and those who identify as LGBTQIA+ in the history of biology were not as readily available at this point. On the other hand, the predominance of female biologists as research subjects for our assignment may also reflect that the demographics of our students in Augustana biology are predominantly female, although our sample for this study contained more males.

Through this capstone course and the addition of this website assignment, we have committed to working to break down the systemic marginalization that has been a part of the history of biology, including education, so that we can move from it being present to it being part of our past. Biology programs should center diversity in our classrooms and assignments, ensuring that our students, regardless of their backgrounds and identities, can envision themselves as biologists and, in turn, become the next generation of biologists, biologists who can have websites spotlighting their accomplishments, while also celebrating their uniqueness.

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Contributions

NH designed the assignment and study, wrote the first draft, and implemented the original assignment. AM revised and subsequently implemented the assignment and study. JK and BM collected and analyzed the data. All authors contributed to drafts after the initial draft.

Biographies

NH is Professor Emeritus, AM is an Associate Professor of Biology and Associate Dean (Undergraduate), and JK is a recent graduate with a BSc in biology. BM was an undergraduate biology researcher from Stato University of Londrina, Brazil. All worked at the Augustana Campus of the University of Alberta while they collaborated on this study.

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Crayfish shelter-seeking behavior as an experimental system to teach experimental design and research skills to undergraduate biology students

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Abstract

During the 2023 – 2024 academic year, a research system based upon the study of crayfish shelter-seeking behavior was developed to facilitate an authentic research experience in a new course for second-year students focused on practicing scientific skills related to evaluating primary literature, designing and conducting experiments, analyzing results, and communicating research findings. Crayfish were utilized due to their availability from local streams and biological supply companies, hardiness and low mortality in aquaria, and their use as experimental models in studies of genetics, neuroscience, and animal behavior. Students evaluated shelter-seeking behavior in response to manipulations of shelter types, substrates, artificial light, and other variables. Crayfish were held in 10-gallon aquaria, provided with shelters, and tested in experimental arenas that students manipulated based upon their research hypothesis. More than 100 students conducted research across six course sections, developing more than 20 unique projects. Students reported results in both written and oral formats, describing substrate and shelter preferences under lab conditions that closely mimic their natural habitats and possible effects of artificial light at night on nocturnal behavior.

Keywords: crayfish, experimental design, undergraduate research

Introduction

The first-year course in biology at Wofford College (BIO 150 Biological Inquiry) exposes students to the process of biological inquiry (Goldey et al. 2012). Biology faculty designed a follow-up, second-year course (BIO 216 Experimental Design, Analysis, and Communication) to introduce students to experimental design and emphasize the practice of biological inquiry through designing and executing research experiences. Criteria for selecting a research system for this course included the ability to generate and test relevant and diverse hypotheses by sophomore-level students, a failure-tolerant system that allowed students to make and correct mistakes, and the capability to carry out experiments over a short (~4 week) time frame. Thus, the course implemented an experience similar to course-based undergraduate research experiences (CURE), which can increase student engagement, achievement, persistence, and inclusion (Kuh, 2008; Auchincloss et al., 2014; Freeman et al., 2014).

In Fall 2023 and Spring 2024, a research system was designed using crayfish, decapod crustaceans with a large global distribution, as experimental subjects. Crayfish are intriguing physiologically, ecologically, and behaviorally but are also imperiled across much of their range (Taylor et al., 2019). Although they are ecosystem engineers that increase nutrient availability in freshwater ecosystems (Reynolds et al., 2013; Albertson and Daniels, 2018), many species are not well studied (Loughman and Fetzner, 2015). Kubec et al. (2018) suggests their suitability for ethological studies and application to many disciplines. Investigation into species-specific behaviors may provide insight into topics such as the spread of invasive crayfishes and displacement of native crayfishes, extirpations from environmental degradation, resilience to climate change, and susceptibility to novel diseases. The marbled crayfish *Procambarus virginalis*, a parthenogenetic crayfish, has emerged as a new laboratory model in developmental biology, stem cell research, epigenetics, and evolutionary biology (Vogt, 2008). Recent analysis has investigated the crayfish's potential as a model for studies of drug addiction (Jackson and Staadan, 2019; Imeh-Nathaniel et al., 2019). Crayfish also have high sociality levels (Figler et al., 1995; Issa et al., 1999) with a high degree of specialization in sensory organs, particularly for communication (Basil and Sandeman, 2000; Kubec et al., 2018). Because of their behavioral and physiological responses to stress, crayfish are suggested as models to study emotional behavior and mechanisms for human affective disorders

(De Abreu et al., 2020).

Crayfish can be aggressive toward each other, resulting in stress, injury, and even cannibalism in captivity (Steele et al., 1997). Thus, when using crayfish as experimental models, proper conditions should be provided that prevent stress, which can improve the quality and validity of experiments (Alberstadt et al., 1995). Although the laboratory housing conditions needed to reduce stress of crayfish warrants further study, enrichment of the environment with shelters is known to reduce aggression and support shelter-seeking tendencies (Capelli and Hamilton, 1984). Various shelter characteristics, such as size, shape, and texture, may affect shelter use. Shelter occupancy can depend upon the darkness provided by the shelter (Alberstadt et al., 1995; Antonelli et al., 1999), the size of the shelter relative to a crayfish's size (Antonelli et al., 1999; Forsythe et al., 2011), the presence of conspecifics (Hill and Lodge, 1994; Quinn and Graves, 1998; Dunham, 1999), and previous occupancy of a shelter (Forsythe et al., 2011).

Thus, many hypotheses can be developed related to crayfish shelter-seeking behavior in captivity. We describe a research system utilizing crayfish for students to develop varying hypotheses and conduct research that is authentic, relevant, and iterative. Students read peer-reviewed papers related to crayfish shelter use, developed a hypothesis, designed and implemented an experiment, analyzed data, wrote a scientific manuscript, and presented results orally. We report examples of common hypotheses tested by students related to shelter-seeking behavior and shelter preference. The diverse hypotheses tested demonstrate the flexibility of this setup.

Course Structure and Design

The integration of the research system into the course is outlined in Table 1. Students were introduced to crayfish as experimental models by

Table 1. Course plan detailing the implementation of the course research experience.

Week	Activity
1	Introduce course learning objectives, project concept, crayfish as model organisms, view preserved crayfish, and rubrics for the final paper and presentation reviewed.
2	Read Kubec et al. (2019) as an introduction to review papers. Complete an activity that dissects the paper. Introduce students to conducting a literature review on a topic.
3	Read Alberstadt et al. (1995) and learn how to analyze a scientific paper. Analyze an additional paper in groups. Conduct a jigsaw activity to practice summarizing a research paper.
4	A science librarian introduces skills of searching scientific literature, and students develop an annotated bibliography on crayfish shelter-seeking behavior. Introduce scientific writing and the structure of Introduction and Methods sections. Begin writing an Introduction.
5	Review hypotheses/predictions, clarify the hypothesis/prediction for student experiments, and identify independent, dependent, and confounding variables. Introduce pseudoreplication and identify potential sources of pseudoreplication in their experiment.
6	Introduce randomized designs, blocking, and repeated measure designs and incorporate concepts into the development of experimental design for project.
7	Assessment of experimental design skills. Construct methods and set up experiment.
8	Test experimental design and begin data collection.
9	Continue data collection.
10	Practice with t-tests and box plots using project data. Continue data collection.
11	Practice with ANOVA and graphs. Continue data collection.
12	Practice with linear regression and scatter plots. Finish data collection and write Results section. Introduce structure of a Discussion section and complete guided activity for writing the Discussion.
13	Data analysis and visualization skills assessment. Submit Discussion draft. Introduce oral presentations.
14	Thanksgiving Break
15	Submit rough draft; develop oral presentation. Receive feedback on rough draft; finish presentation.
16	Submit final manuscript and give presentation.

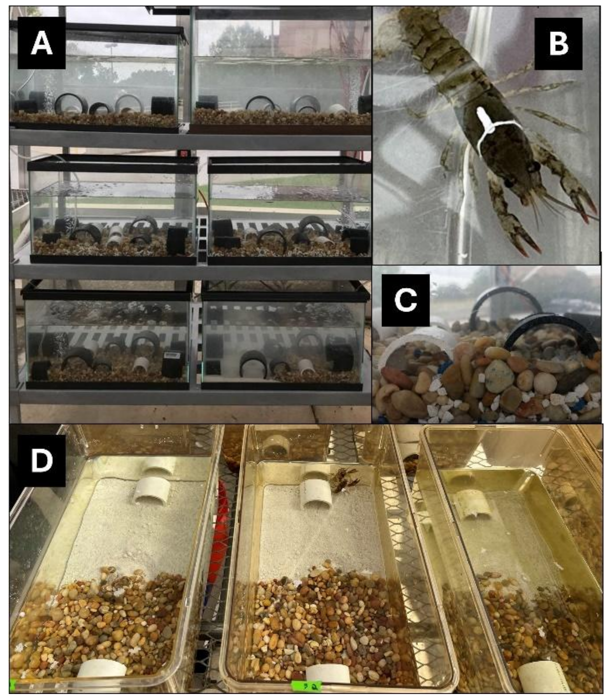
reviewing peer-reviewed literature, particularly Kubec et al. (2019), Alberstadt et al. (1995), and Antonelli et al. (1999). Students constructed an annotated bibliography to summarize relevant studies and then developed a hypothesis.

To develop their methodology, students received instruction in experimental design and then set up experimental arenas and conducted pilot studies. Students completed four weeks of data collection, during which they were trained in data analysis (i.e., t-tests, analysis of variance, and linear regression), analyzed data using JMP Pro 16 (SAS Institute, Inc.), and designed figures for their results. All students developed a manuscript that followed the IMRAD (Introduction, Methods, Results, and Discussion) format that was written in sections throughout the course. Using the annotated bibliography, students wrote an Introduction (Week 4) and then wrote the Methods section after developing their experimental design (Week 8). The Results section was written after completing data analysis (Week 12) followed by the Discussion section (Week 13) with a rough draft due at the beginning of Week 15, which was dedicated to improving the draft and constructing an oral presentation. During the final week, students submitted the final draft and presented their research.

Common Methodology for Crayfish Research

Approximately two weeks before field collection (Week 5), aquaria were set up in a laboratory or greenhouse for housing crayfish (Figure 1). Aquarium gravel was added to 10-gallon aquaria to create a 2.5 – 5.0 cm layer of substrate. Water was treated with tap water conditioner to remove chlorine and received constant aeration. At least one shelter per crayfish was added to each tank. Shelters consisted of either small, hand-sized rocks taken from the source stream, or small lengths (~ 5 – 7.5 cm) of 3.8 – 7.6 cm diameter PVC pipe. PVC was buried into gravel substrates to provide a flat surface for crayfish. Because crayfish would excavate gravel from the PVC shelter, pipes were subsequently cut in half and placed on the substrate. In the laboratory, lighting was set to 16:8-hour schedule of light to darkness and provided by overhead fluorescent lighting. In the greenhouse, crayfish were subjected to the normal photoperiod of the environment.

Figure 1. Photographs of Experimental System. **A:** Ten-gallon source tanks with PVC shelters partially buried in gravel. **B:** Variable crayfish (*Cambarus latimanus*) individually marked on the dorsal surface of the cephalothorax with a paint pen. **C:** PVC shelters partially buried in gravel in source tanks. **D:** Experimental arenas divided into two halves with sand and gravel substrates and PVC shelters.

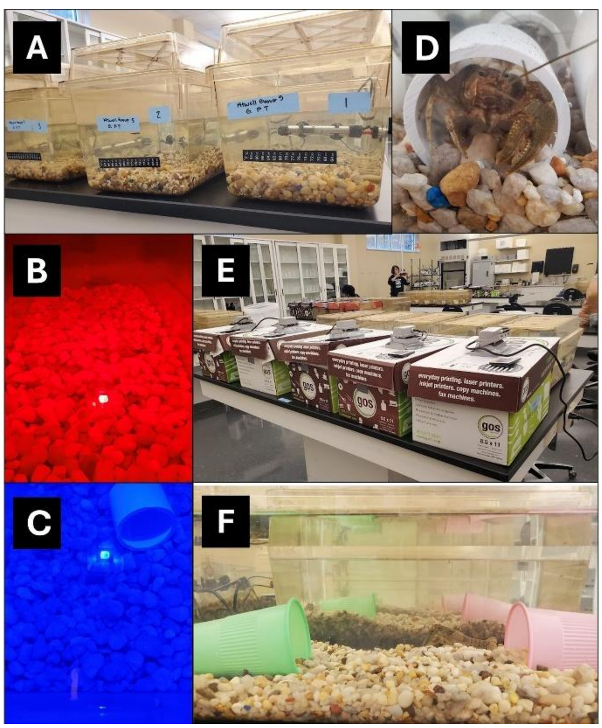


In Week 6 two crayfish species (*Cambarus latimanus* and *Cambarus chattahoochee*) were collected from a small (~2 – 3 m wide) stream in Spartanburg, South Carolina approximately 3 km from Wofford College. Approximately 12 – 15 crayfish were collected for each team of student researchers. During collection, crayfish were held in 5-gallon buckets of stream water and then transported to the college. Upon arrival, crayfish were acclimated to the system water source by adding ~ 1 quart of treated dechlorinated aquarium water every 15 minutes to buckets until water temperatures were similar between buckets and aquaria, and then crayfish were added to aquaria. Additionally, red swamp crayfish *Procambarus clarkii* were ordered from Carolina Biological Supply in Spring 2024 for use. Wire screens covered every tank, and a heavy object was placed on top of aquaria to prevent escape.

Crayfish were allowed to adjust to source tanks for at least 48 hours before any experimentation. Crayfish were fed every 2 days, water temperature and dissolved oxygen were checked daily, and water changes were conducted once per week over a 4-week experimental period. After 48 hours, crayfish were removed from their tank, measured for carapace length, and had a unique number written on the dorsal side of their carapace with a paint pen (Ramalho et al., 2010).

Students tested hypotheses by removing crayfish from source tanks and placing them into experimental arenas that students could manipulate (Figure 2). These arenas were subjected to the same environmental conditions, including air temperature, lighting, and water temperature, unless the hypothesis necessitated manipulation of one of these. Arenas were plastic containers approximately 46–cm x 25–cm x 20.5–cm with fitted covers and a layer of substrate. Substrate composition and shelter characteristics varied based upon experimental manipulations. In some cases, barriers were placed between adjacent arenas to reduce the influence of crayfish in nearby arenas on behavior. Crayfish were placed into an arena and observed over a defined period by students.

Figure 2. Photographs of Experimental System II. A: Experimental arenas in the laboratory with varying water temperatures. **B:** Red swamp crayfish (*Procambarus clarkii*) inhabiting a PVC shelter in a source tank. **C:** Red light manipulation in an experimental arena. **D:** Blue light manipulation in an experimental arena. **E:** Laboratory setup of experimental arenas showing cardboard covers embedded with lights. **F:** Experimental arena providing crayfish with choice between two color options.



Examples of Student Experiments

In Fall 2023 and Spring 2024, six sections of the BIO 216 course implemented this experimental system with ~110 students collaborating to complete 28 research projects. Using experimental arenas, many students designed choice experiments, and observed choices made by crayfish. The following are examples of experimental designs developed by students and their results.

Alberstadt et al. (1995) and Antonelli et al. (1999) tested shelter choice of crayfish when manipulating thigmotactic (i.e., shelter size in comparison to crayfish size) and darkness cues provided by shelters by using clear or opaque glass beakers of varying sizes. For experimentation, students typically introduced crayfish into an arena, observed them over an 8-hour period, and scored them as occupying a particular shelter type. Shelter arrangement and position in each arena was randomized in most experiments. One team of student researchers provided crayfish with the choice of two shelters – a clear glass beaker half-buried in gravel substrate and a clear beaker completely covered by gravel substrate to provide darkness Another team implemented a repeated measures design that randomly assigned crayfish to three experimental arenas, which included shelter choices among a flat, hand-sized rock, a PVC pipe, and a dark glass beaker.

Activities such as deforestation, urbanization, and agriculture contribute excessive sediment to stream substrates, covering rocky and gravel substrates, and filling interstitial spaces and crevices utilized by crayfish (Swank et al., 2001; Taylor et al., 2007; Richman et al., 2015). Therefore, students manipulated substrates in experimental arenas, providing crayfish choices between gravel, sand, and mixed sand-gravel substrates, to make inferences about the effect of sedimentation on crayfish behavior. Students standardized the shelter type, and the arena was divided into left and right sections with each section containing a different substrate. Other students approached the issue of sedimentation by manipulating water quality and increasing the turbidity of the water column. Students designed an experiment with treatments consisting of three levels of suspended sediment in the water column.

As nocturnal animals, crayfish typically emerge from shelters at night, but in the presence of artificial light at night (ALAN), they may spend more time under shelter, decreasing foraging time and interaction with other crayfish (Thomas et al., 2016; Fischer et al., 2019). Various colors of light and the use of LED lights can alter behavior also (Ruokonen et al., 2021; Suryanto et al., 2023). To evaluate the effects of ALAN, students exposed crayfish to varying light intensities and colors at night, placing crayfish in covered arenas fitted with LED lights with PVC shelters at either end of the arena (Figure 2). During nighttime darkness, experimental arenas containing a single shelter were exposed to four treatments of light, no light, white light, red light, and blue light.

Discussion

A research system for studying crayfish shelter-seeking behavior was utilized to prepare second-year biology majors for more intensive research experiences as third- and fourth-year students. The research system provided the opportunity for students to develop authentic, relevant, and diverse research questions, and many other questions can be asked in this system related to animal behavior, light pollution, sedimentation of streams, urbanization, and climate change through manipulations of shelters, substrates, light, water temperature and other variables.

This system allowed students to test hypotheses related to shelter-seeking behavior while also building their skills in experimental design, quantitative analysis, and communication. In the research system students applied experimental design concepts of hypothesis development, use of controls, randomization, replication, and blocking. Students designed a randomized process to select crayfish from source tanks using a list of computer-generated numbers after many initially proposed haphazard sampling methods (i.e., attempting to grab a crayfish out of a source tank without bias). Pseudoreplication was considered by randomizing locations of arenas in labs or greenhouses or the location of shelters in arenas and treating results from arenas as experimental units rather than individual crayfish. Some students applied concepts of blocking by equally dispersing crayfish of varying sizes among treatments or arenas. In some cases, students designed repeated measures studies in which individual crayfish were exposed to multiple treatments, randomizing the order of treatment exposure.

This research system provided students with autonomy in hypothesis development and experimental design, but students were steered toward viable designs through reading assignments early in the course, including Alberstadt et al. (1995), Antonelli et al. (1999), Forsythe et al. (2003), Capelli and Hamilton (1984), and Fischer et al. (2020). This avoided impractical research experiences due to space, time, and financial constraints and helped students navigate indecisiveness that could delay the project. Even so, some students procrastinated through group indecision or by displaying perfectionist tendencies. Instructors may need to facilitate group decision-making and encourage pilot studies to test the experimental design.

An emphasis on experimental design theory was necessary prior to the start of data collection and encompassed 3 – 4 weeks of the course. To avoid a disconnect between the theory and skill of experimental design and the forthcoming research project, it is recommended to integrate the two. For example, when teaching randomization, students completed an activity which incorporated randomization into their design and the crayfish research system. This resulted in piecemeal construction of the experimental design, leading to a completed course unit focused on analyzing data with common statistical methods (e.g. t-test, ANOVA, regression, etc.) and visualizing the data, and class sessions were designed to incorporate the analysis of available data from the research projects into the lesson. Because this unit coincided with the completion of data collection, students were able to produce their results and figures quickly and efficiently. A flipped learning approach that utilized pre-class video lectures and assessments was implemented such that in-class meetings could be dedicated to guided activities on experimental design and data analysis.

With class enrollments capped at 16 students, group sizes were limited to 3 or 4 students, and each group was provided with one source tank containing 12 – 15 crayfish and 3 – 4 experimental arenas. Larger classes or small groups sizes result in more groups which greatly expands the size of the research operation, including the equipment, space, and crayfish needed. In both semesters, a shared lab space and a small area (3m x 3m) in a greenhouse was dedicated to accommodating the research setup.

The necessity of reviewing peer-reviewed literature and introducing experimental design theory prior to data collection resulted in the start of data collection coinciding with either fall break or spring break, creating logistical problems in the timing of acquiring crayfish and maintaining them in aquaria during the break. Starting data collection after these breaks either reduces the data collection period or limits the time for composing the final paper and presentation and for addressing any issues with crayfish mortality or equipment malfunction. In the next iteration of the course, some experimental design concepts may be excluded to allow for an earlier start to research. Teaching assistants were critical to maintaining the research system and addressing any issues, limiting the workload for faculty.

An authentic research experience for undergraduates was provided using a research system focused on the shelter-seeking behavior of crayfish. Undergraduate research is a high-impact practice where students practice inquiry, analyze primary literature, generate ideas, apply knowledge through experimentation, develop communication skills, and connect with faculty and peers (Kuh, 2008; Brownell and Kloser, 2015). Students experience gains in resilience, academic identity (Mraz-Craig et al., 2018), self-confidence (Bascom-Slack et al., 2012; Prunuske et al., 2013), content knowledge (Makarevtich et al., 2015; Ward et al., 2014), and self-efficacy (Frantz et al., 2006). Participation in research also improves retention, completion rates, and graduate school enrollment (Junge et al., 2010; Brew and Mantai, 2017). Multiple course sections successfully implemented the experience over two semesters with different instructors, and students developed diverse hypotheses to test with success leading to further implementation in Fall 2024 and students building on previous research. The experience allowed students to develop competence in hypothesis development, experimental design, data analysis, and oral and written communication and emphasized practice of these skills. Lastly, crayfish are an active invertebrate subject for students to study and can serve as an engaging entry point for students new to research.

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Beasts with Best Reponses:
Fresh Examples for Teaching Game Theory in Undergraduate Biology Courses

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Abstract
Game theory has been central to understanding animal behavior for over fifty years, yet undergraduate biology students are often exposed to only a narrow set of canonical examples, such as the hawk-dove game and the prisoner's dilemma. This paper introduces two fresh, research-grounded examples designed to enrich game theory instruction in undergraduate biology courses: (1) gray wolf self-domestication as a hawk-dove game and (2) northern lapwing nesting decisions as a coordination game. Each example highlights distinct strategic dynamics – competition and coexistence in the wolf game, and coordination and payoff dominance in the lapwing game – while extending naturally to discussions of evolutionary stability. To support flexible teaching, we provide handouts, an in-class activity, simulation tools, and AI tutoring prompts that help students engage with the material both in and out of class. Our aim is to make game theory more accessible, engaging, and biologically relevant, thereby strengthening students' quantitative reasoning.

Keywords: Game theory, animal behavior, evolutionary biology, active learning, classroom activities, quantitative skills, AI tutoring.

Biologists have used game theory to understand strategic inter- and intraspecific interactions in nature for more than 50 years (Maynard Smith and Price, 1973), but undergraduate biology students receive relatively little training in game theory, with many textbooks in animal behavior and evolutionary biology devoting just a page or two to the topic (e.g., Rubenstein and Alcock, 2018; Herron and Freeman, 2020; Futuyama and Kirkpatrick, 2023). This may be a missed opportunity. Because game theory is a subfield of mathematics, incorporating it into undergraduate courses addresses students' growing interest in quantitative skills (Coffey, 2024). And because game theory is widely used in economics (Dixit et al., 2025), political science (McCarty and Meirowitz, 2007), and international relations (Kydd, 2015), game theoretic examples have broad interdisciplinary appeal. Game theoretic examples also naturally lend themselves to classroom activities that can make the topic more engaging and, as a result, more memorable.

We present a pair of examples that are grounded in scientific research, that complement the hawk-dove and prisoner's dilemma examples found in many textbooks, and that highlight the importance of competition and coordination in animal behavior. Instructors can use one or both of these examples in different ways depending on how much time they wish to devote to game theory. We also provide handouts, assignments, instructions for an in-class activity, and interactive AI tutoring prompts instructors can use alongside these examples.

The most straightforward approach is to use the first example (gray wolf domestication) in class as way to explain concepts like best response and Nash equilibrium without simply restating the classic hawk-dove example (Maynard Smith and Parker, 1976) often found in textbooks. This would require no more class time than the standard presentation but may be more interesting for students who have already read about the classic game.

Instructors interested in spending a bit more time on game theory can pursue one or both of the examples further, introducing students to evolutionary stability. Alternatively, an instructor could walk through one of the examples in class, reserving the other example for an assignment students complete outside of class.

Gray wolf self-domestication as an example of a hawk-dove game

Dogs (*Canis familiaris*) are domesticated gray wolves (*Canis lupus*). Some researchers (e.g., Larson and Fuller, 2014) hypothesize that wolves initially domesticated themselves, with the friendliest, least timid wolves approaching human hunter-gatherer groups in order to eat the humans' food scraps.

This can be modeled as a hawk-dove game where two wolves must simultaneously decide whether to play Friendly or Timid. The payoff matrix presented in Figure 1 shows two wolves' payoffs in fitness points as a function of how each wolf behaves around humans. The row wolf's best response is to play Timid with humans when the column wolf plays Friendly, and its best response is to play Friendly with humans when the column wolf plays Timid. The same reasoning applies to the column wolf, so the game has two pure-strategy Nash equilibria: (***Friendly***, Timid) and (***Timid***, Friendly). At either of these equilibria, neither player can improve its own payoff by changing its own strategy. Unlike the prisoners' dilemma (Tucker, 1983), which has a unique Nash equilibrium, this game has multiple possible equilibria. Some students may find this counterintuitive. If the row wolf gets its highest possible payoff when it plays Friendly, why not always play Friendly? But game theory does not ask which strategy yields the best absolute payoff, it asks which strategy is the best response to the other player's behavior. If the row wolf anticipates the column wolf will play Friendly, then playing Timid earns it 3 fitness points, which is more than the 2 it would earn by matching friendliness.

An instructor might ask the students whether it is realistic to assume that non-human animals think through their options strategically. If not, why use game theory to describe animal behavior at all? The answer is natural selection. Wolves do not need to think rationally; some are simply born with tendencies that approximate best responses to the social games they face. These wolves tend to reproduce more successfully, so over time the population evolves with increasing numbers of individuals employing strategies that are best responses, even in the absence of conscious thought.

An instructor can take things a step further by discussing whether a given population state is evolutionarily stable, meaning it cannot be successfully invaded by mutants playing a different strategy. To do this, the instructor could rewrite the payoff matrix solely in terms of the

		Column wolf	
		Friendly	Timid
Row wolf	***Friendly***	(***2***, 2)	(***5***, 3)
	Timid	(***3***, 5)	(***2***, 2)

Fig. 1. Payoff matrix for the wolf-dog game. All payoffs are measured in fitness points, where a higher payoff is better. Each cell shows payoffs as (***Row payoff***, Column payoff). The two pure-strategy Nash equilibria are (***Friendly***, Timid) and (***Timid***, Friendly).

row wolf's payoffs, as seen in Figure 2, then calculate the row wolf's expected payoff assuming q is the proportion of column wolves playing Friendly[1]. Thought of another way, if the row wolf randomly encounters another wolf from the population, that wolf will play Friendly with probability q.

Figure 3 presents these expected payoffs graphically, with fitness on the vertical axis and the proportion of the population playing Friendly on the horizontal axis. Focusing on the monomorphic state where all wolves play Friendly (i.e., where $q = 1$), a mutant playing Timid will have a higher expected payoff (3 fitness points versus 2). It will therefore be more successful reproductively, and the proportion of wolves in the population playing Timid will increase over time. Likewise, in a monomorphic state where all wolves play Timid (i.e., where $q = 0$), a mutant playing Friendly will have a higher expected payoff (5 fitness points versus 2). It will therefore be more successful reproductively, and the proportion of wolves in the population playing Friendly will increase over time. This shows that either monomorphic state can be successfully invaded by mutants, meaning neither of these population states are evolutionarily stable.

Intrepid students might ask about the point where the two expected-payoff lines cross. This point represents a polymorphic population where

		Column wolf		
		Friendly (q)	Timid ($1-q$)	Row wolf's expected payoff
Row wolf	***Friendly***	***2***	***5***	$\mathrm{E}(\pi_{Row}^{Friendly}) = 2q + 5(1-q) = 5 - 3q$
	Timid	***3***	***2***	$\mathrm{E}(\pi_{Row}^{Timid}) = 3q + 2(1-q) = 2 + q$

Fig. 2. Payoff matrix showing Row wolf's expected payoff as a function of the population playing Friendly. The proportion of the population playing Friendly is denoted by q. Expected payoffs are measured in fitness points, where a higher payoff is better.

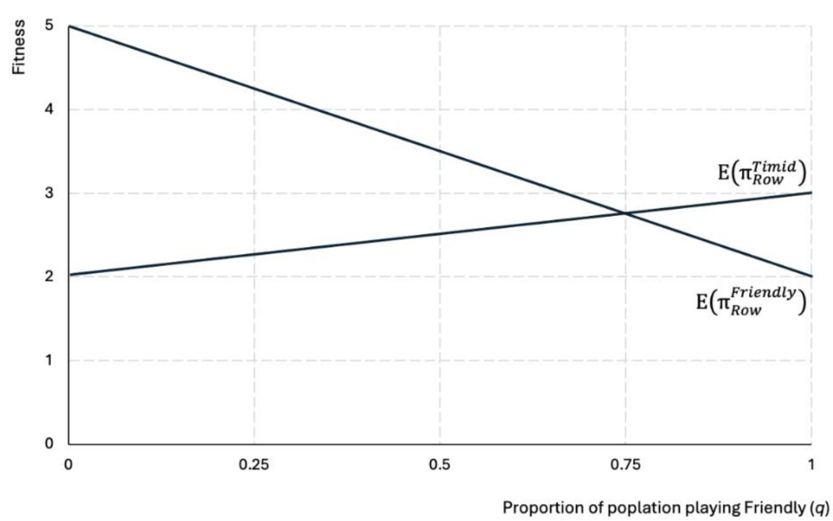

Fig. 3. Plot showing Row wolf's expected payoff as a function of the population playing Friendly. The proportion of the population playing Friendly is denoted by q. Expected payoffs are measured in fitness points, where a higher payoff is better.

[1]Following common practice in game theory, we use π to represent *payoff* in Figure 2 and later in Figure 5. Instructors may want to point out that this is distinct from the more common use of π to represent the mathematical constant roughly equal to 3.14.

3/4 of wolves play Friendly and 1/4 play Timid. At this critical point, wolves playing Friendly have the same fitness as wolves playing Timid, meaning neither has an advantage over the other and there is no tendency for the population to change. This is the game's unique evolutionarily stable population state. If a population that starts at q = 0.75 is somehow perturbed such that q > 0.75, wolves playing Timid will be fitter than wolves playing Friendly, meaning the proportion of wolves playing Friendly will decrease over time until the population returns to q = 0.75. Similarly, if the population is perturbed such that q < 0.75, wolves playing Friendly will be fitter than wolves playing Timid, meaning the proportion of wolves playing Friendly will grow over time until the population returns to q = 0.75.

Instructors can find a handout presenting this example at bit.ly/4ltNBSs. Depending on what instructors think is most appropriate for their class, they can provide this handout to students to work through as the instructor presents the material on the board, they can provide class time when students can work through the packet on their own or in small groups, or they can have students complete the handout outside of class as an assignment. We also provide the instructions for an in-class activity at bit.ly/45z6SMS. In this activity, students are assigned the role of either a friendly or timid wolf, then play the game from Figure 1 with five of their classmates. A student's total fitness score from these five rounds determines whether they would have one, two or three offspring. If an instructor assigns relatively few students to the friendly role (e.g., q = 0.15), students will see that friendly wolves dramatically outperform timid wolves, such that virtually all wolves with three offspring are friendly. In the interest of time, an instructor can use the Excel simulation for this exercise (bit.ly/4oOFQsl) to show how the outcome would be different when a given wolf goes has a 90% chance of being friendly. In this case, wolves having multiple offspring are disproportionately timid.

If students complete the handout for this game as a homework assignment, instructors may also want to provide them with the AI tutoring prompt available at bit.ly/40ZwUWP. This closely follows a prompt developed by Mollick and Mollick (2025). Students can copy the entire text of this prompt, paste it into the AI of their choosing, and then upload the assignment. Using this prompt, the AI will provide students with guidance and useful hints but will not simply present them with answers. Early evidence from Bastani et al. (2025) suggests that the deliberate feedback provided by this kind of AI tutor has a large positive effect on homework performance without harming performance on exams[2]. Another alternative would be to provide students with the AI prompt in the lead up to the next exam. Students could then use the AI tutor as a way to quickly review the handouts as they prepare for the exam.

In the next section, we present another evolutionary game. Instructors can present this new game instead of or in addition to the wolf domestication game. Alternatively, instructors can present one game in class, then send students home with the handout for the other game to complete as an assignment.

Northern lapwings' strategic nesting decisions as an example of a coordination game

The northern lapwing (*Vanellus vanellus*) is a Eurasian shorebird that nests in wetlands and farmlands (Cevenini et al., 2025). Its choice of nesting site is strategic because a nest built on farmland is less likely to be preyed upon when other lapwings build their nests nearby (Tilgar et al., 2024).

The nesting decision can be modeled as a coordination game where two lapwings must simultaneously decide whether to play Farmland or Wetland. The payoff matrix presented in Figure 4 shows two lapwings' payoffs in fitness points as a function of each bird's nest site selection behavior. Each cell shows payoffs as (***Row payoff***, Column payoff). The row lapwing's best response is to play Farmland when the column lapwing plays Farmland, and its best response is to play Wetland when the column lapwing plays Wetland. The

[2]The authors find that access to AI without the tutoring framework has a smaller positive impact on homework performance and a negative impact on exam performance, suggesting students use the AI as a "crutch," perhaps by simply pasting questions into the AI, then copying the answers.

same reasoning applies to the column lapwing, so the game has two pure-strategy Nash equilibria: (***Farmland***, Farmland) and (***Wetland***, Wetland). At either of these equilibria, neither player can improve its own payoff by changing its own strategy.

While this closely resembles the hawk-dove game, coordination games differ in that the two pure-strategy Nash equilibria involve each player matching the other's strategy. This particular game also differs from the one in the previous section in that the (***Farmland***, Farmland) Nash equilibrium leaves both players better off than the (***Wetland***, Wetland) Nash equilibrium. Game theorists would say the (***Farmland***, Farmland) Nash equilibrium is payoff dominant.

An instructor could end the formal game-theoretic analysis here and segue into a discussion of whether we can be sure the lapwings will end up at the payoff-dominant equilibrium where both nest in farmland. Most students can quickly come up with examples of situations where evolution has produced an outcome that would clearly seem to leave individuals worse off than they could be. And that is consistent with the game. If one lapwing builds its nest in wetlands, the other lapwing can do no better than to build its nest in wetlands. That is true even though the birds would obviously be better off if they both built their nests in farmland.

In this sense, this game also resembles the classic prisoners' dilemma, where the unique Nash equilibrium leaves both players worse off than they would have been if they had both played their other strategy. But what makes this game different is that if one lapwing builds its nest in farmland, the other lapwing can do no better than to build its nest in farmland as well.

As with the previous example, instructors interested in devoting more time to game theory can extend this example by discussing whether a given population state is evolutionarily stable. To do this, the instructor could rewrite the payoff matrix solely in terms of the row lapwing's payoffs, as seen in Figure 5, then calculate the row lapwing's expected payoff assuming the column lapwing is a random draw from a population where q is the proportion of lapwings playing

		Column lapwing	
		Farmland	Wetland
Row lapwing	***Farmland***	(***4***, 4)	(***2***, 3)
	Wetland	(***3***, 2)	(***3***, 3)

Fig. 4. Payoff matrix for the lapwing game. All payoffs are measured in fitness points, where a higher payoff is better. Each cell shows payoffs as (***Row lapwing***, Column lapwing). The two pure-strategy Nash equilibria are (***Farmland***, Farmland) and (***Wetland***, Wetland).

		Column lapwing		
		Farmland (q)	Wetland ($1-q$)	Row lapwing's expected payoff
Row lapwing	***Farmland***	***4***	***2***	$\mathrm{E}\left(\pi_{Row}^{Farmland}\right) = 4q + 2(1-q) = 2 + 2q$
	Wetland	***3***	***3***	$\mathrm{E}\left(\pi_{Row}^{Wetland}\right) = 3q + 3(1-q) = 3$

Fig. 5. Payoff matrix showing Row lapwing's expected payoff as a function of the population playing Farmland. The proportion of the population playing Farmland is denoted by q. Expected payoffs are measured in fitness points, where a higher payoff is better.

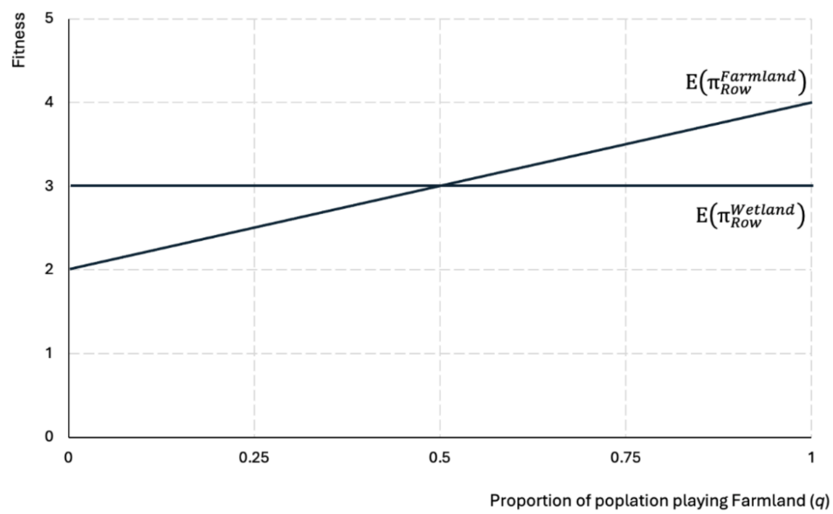

Fig. 6. Plot showing Row lapwing's expected payoff as a function of the population playing Farmland. The proportion of the population playing Farmland is denoted by q. Expected payoffs are measured in fitness points, where a higher payoff is better.

Farmland.

Figure 6 presents these expected payoffs graphically, with fitness on the vertical axis and the proportion of the population playing Farmland on the horizontal axis. Focusing on the monomorphic state where all lapwings play Farmland (i.e., where q = 1), a mutant lapwing playing Wetland will have a lower expected payoff (3 fitness points versus 4). It will therefore be less successful reproductively, and its mutant strategy will be unlikely to spread through the population. Likewise, in a monomorphic state where all lapwings play Wetland (i.e., where q = 0), a mutant lapwing playing Farmland will have a lower expected payoff (2 fitness points versus 3). It will again, be less successful reproductively, and its mutant strategy will be unlikely to spread through the population. This shows that neithermonomorphic state can be successfully invaded by mutants, meaning both of these population states are evolutionarily stable.

Again, students may ask about the point where the two expected-payoff lines cross. This point represents a polymorphic population where 1/2 of lapwings behave by playing Farmland and 1/2 behave by playing Wetland. At this critical point, lapwings playing Farmland are just as fit as lapwings playing Wetland, meaning neither has an advantage over the other and there is no tendency for the population to change. But unlike the example in the previous section, this critical point is not an evolutionarily stable population state. If a population that starts at q = 0.5 is somehow perturbed such that q > 0.5, lapwings playing Farmland will have higher fitness than those playing Wetland, meaning the proportion of lapwings playing Farmland will continue to grow until the population reaches to q = 1. Similarly, if the population is perturbed such that q < 0.5, lapwings playing Wetland will have higher fitness than those playing Farmland, meaning the proportion of lapwings playing Farmland will continue to decrease until the population reaches q = 0.[3]

Instructors can find a handout presenting this example at bit.ly/40pjvXW. The handout can be completed inside or outside of class. If completed outside of class, instructors may want to provide students with the AI tutoring prompt described in the previous section (bit.ly/40ZwUWP).

[3]In this example, we assume that lapwing breeding density never becomes high enough to cause overcrowding, which would otherwise reduce individual fitness or prompt birds to switch strategies and nest in an alternative habitat

Conclusion

Biologists have used game theory to explain animal behavior for more than 50 years (Leimar and McNamara, 2023.). The tools of game theory are so widely accepted that evolutionary biology and animal behavior textbooks now routinely include game theoretic examples complete with payoff matrices and discussions of Nash equilibrium (e.g., Bergstrom and Dugatkin, 2023; Nordell and Valone, 2024). However, this coverage is usually quite limited and rarely tied to a biologically relevant example grounded in empirical evidence. Instructors who are interested in presenting students with alternatives to the examples normally found in textbooks can use the framing and payoffs from either of the examples in this paper. Instructors who want to devote more class time to game theory can extend either or both of these examples through informal discussion or through a formal presentation of evolutionary stability. Interested instructors can supplement this formal presentation with the handouts and AI tutoring prompts we provide.

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Corrigan, J.R & Levin: Appendices

Lapwing Game.docx

AI Tutor Prompt.docx

In-Class Activity.docx

In-Class Activity Simulation.xlsx

Lapwing Game.docx

Wolf Game.docx

Innovations

Emphasizing the challenges of scientific communication using an icebreaker activity

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Abstract

Effectively communicating scientific information is essential not only for advancing a specific field but also for building key relationships between researchers and society. One of the key challenges of this is the ability to translate highly technical terms into digestible concepts. Within my upper-level cellular biology course, students often underestimate this challenge. Therefore, I emphasize the importance of effectively translating biological terms early in the semester using a simple icebreaker activity. This activity combines the methodology of a party game with increasingly technical biological terms. In this multi-round activity students are challenged to draw and communicate using limited starting information. This in turn pushes students to not only think creatively about how to depict scientific terms but also realize the difficulty in doing so. Moreover, this game gets students interacting early in the semester and can result in humorous outcomes which helps break tension and promote an interactive learning environment.

Keywords: Icebreaker, Biology, Cellular Biology, Communication

Introduction

Effective scientific communication is imperative for the dissemination of information within and across biological disciplines. Moreover, effective communication allows scientists to educate the general public in specific fields (Brownell et al., 2013; Leshner, 2003). This is particularly important when addressing and interpreting topics that may be politically controversial (Walker et al., 2017). Practicing proper scientific communication skills is also essential for successful collaboration across biological disciplines and fostering inclusion across diverse biological communities (AAAS, 2011). Therefore, increasing attention has been raised to emphasize the importance of scientific communication skills within the undergraduate curriculum (Dahm et al., 2019; Lewenstein, 2015)

One approach to raising awareness of the importance of scientific communication can be through an icebreaker activity. Icebreakers have been traditionally used within the college classroom to encourage student interaction at the beginning of a course. These activities have been shown to initiate community building, foster communication, and enhance student engagement (Holbert, 2015; Hoseini Shavoun et al., 2024). The use of icebreakers also aids in building a positive learning environment (Richie Ynot Mepieza, 2023). This is of particular importance as increasing a sense of belonging within biology courses has been associated with increased student retention (Wilton et al., 2019). Moreover, icebreakers can be a valuable tool to introduce topics that are important to a course (Fitria, 2023).

While icebreakers have become a common tool at the beginning of a course, research on the undergraduate student perspective of icebreakers and their benefit can be conflicting. For example, undergraduate student surveys relate that students found less value if the icebreaker activity did not directly relate to the class (Kleinschmit et al., 2020). Moreover, some students have reported that the ice breakers activities are boring or seem cliché (Eggleston & Smith, 2010). In attempts to break away from the traditional mold of icebreakers, I have modified a common party game into a communication-based activity. The intention is to use a game that may be familiar to students to emphasize a topic that has a growing importance in biological disciplines: scientific communication.

The icebreaker activity being presented was used in an upper-level cellular biology laboratory course. Undergraduate students in cellular biology often struggle to explain concepts in areas such as genetics and cellular communication (Flowers et al., 2023). While students may attend lectures to familiarize themselves with these topics, educators must provide opportunities for students to put this communication into practice. Moreover, students may be overconfident, unaware that the ability to clearly articulate these concepts is more challenging than initially seems. While the course does incorporate numerous writing activities, the goal was to integrate an early intervention to raise awareness of the challenges with scientific communication in cellular biology in an interactive and humorous way.

The primary goals of the proposed icebreaker activity were to implement a budget-friendly activity that challenges students to reflect on scientific communication challenges and promote student interaction through gamification. After using this activity over the course of two semesters, I have found that it is easy to modify and has challenged students to realize difficulties in interpreting advanced cellular biology terms.

Procedure

Supplies

To complete this activity within a course, you will need the supplies listed in Table 1.

Preparing the activity

Assemble whiteboard cards into a stack held together by a binder clip. Prepare one stack of cards per student group. Additionally, each group should receive an eraser (we use a small microfiber cloth) and a whiteboard marker. Terminology must be generated for the game, ideally with terms that relate to course content. Given this activity was used as an icebreaker on the first day of class, I chose terms for the first round that students should be familiar with from introductory biology. For rounds two and three I chose terms that were more advanced (topics we will be discussing in the course) and those that may be used in popular news/media. Terms were provided on individual slips of paper. I chose to give each group a unique term for each round to maximize the number of terms to be used during the game. Example terminology used in my cellular biology course can be found in Table 2.

Activity overview

This activity is modeled with the framework from Telestrations which is a combination of both the game "telephone" and Pictionary, where groups of players are challenged to pass along terminology through alternating drawing and interpretation. One individual in the group will start the game, receiving a stack of whiteboard

Table 1: Supplies needed for the icebreaker activity.

Item	Quantity Needed	Purpose
3" x 5" whiteboard cards	A stack of whiteboard cards for each group. Each stack must have a whiteboard card for each student (e.g., a group of six students receives a stack of six cards)	To write down terms/draw images during a round.
Binder clips	One per group	To hold the whiteboard cards together in a stack
Whiteboard markers	One per group	For illustrating and drawing
Erasers	One per group	To clear the boards after a complete round.
Timer	One for the instructor	To track the timing of the rounds
Slips of paper with terminology	One slip per group, per round (e.g., for three groups doing three rounds you would need at least nine total slips, each with a term)	Used to start each round- term is provided on slip of paper that the individual can keep secret.

Table 2: Example of terminology used in a cellular biology lab course.

Round 1:	Rounds 2+:
Cell	Cloning
DNA	Stem cells
Microscope	Transcription
Mitochondria	Translation
Nucleus	CRISPR

cards, marker, and a slip of paper with a term (see Table 2 for example terms). This individual must look at the term in secret and draw a representation on the top whiteboard card. Then, the student passes the whiteboard stack to the person on their right. This individual then observes the drawing in secret, places that card on the bottom of the whiteboard stack and uses a new whiteboard card to write down the term that they believe the drawing represents. The stack is then passed to the individual on their right. This individual observes the top card with the term in secret, places that card at the bottom of the stack, and then draws a representation of the term on a new whiteboard card. The pattern continues, with the stack of cards being passed throughout the group alternating drawing and writing until it reaches the starting individual, concluding the round. The group then spreads the cards out to observe the progression of the term throughout the round. To win Telestrations, players must accumulate points. Points are awarded to the individual who generated the most creative drawing and the individual who had the group's favorite guess. A point is also given to the individual who started the round if the final term/guess matches the initial term. At the conclusions of all rounds (the game) the individual with the most points wins.

Executing the activity within the classroom

Within my laboratory course I had three groups of students (5-6 students per group) and conducted three rounds of the game. Students were grouped by lab benches, allowing them to pass their cards around the table. I explained the goals of the game and gave an opportunity for students to ask for clarification before starting. I then asked for student volunteers to start the round (alternatively, you can pick a random student in each group to begin). This student received a stack of whiteboard cards attached with the binder clip, marker, and a biological term on a slip of paper. I provided 1 minute for students to draw with a 30-second warning to encourage students to finish on time. Students then passed the whiteboard stack to the person on their right. This individual saw the drawing in secret, placed that card at the bottom of the stack, and wrote a term. I provided 1 minute for students to write their answer (with 30 second warning). Students alternated writing and drawing, passing the stack around until it reached the initial person who started the round. At the end of each completed round, students laid the cards out in order of completion. Student groups assessed whether their round was successful or unsuccessful (Fig. 1). I asked student groups to keep track of which rounds were successful as they progressed through the game. I also encouraged students to take notes as to why they may have struggled with a particular round. While points are awarded to individuals in Telestrations, the goal of the game in my course was to have students reflect on communication difficulties. Therefore, individual points were not awarded, and there were no individual winners.

Reflection and debrief

There were two levels of discussion for this activity. The first was a small group discussion (held after each round) and the second was with whole class discussion (held at the conclusion of the game). At the end of each round, student groups have 2-3 minutes to figure out if they were successful in maintaining the same term throughout the round. They were also encouraged to discuss any challenges (e.g.- did anyone have difficulty guessing a term or drawing a representation?). Upon completion of all rounds and the conclusion of the game, discussion was opened to the whole class. Groups considered questions (Table 3) for 2-3 minutes after which representative(s) from each group shared their experiences. The class discussions last 5-10 minutes.

Figure 1: Example of a successful and unsuccessful round. (A) Students began with the term “DNA” and agreed that the last drawing illustrated this. (B) The first student received the term “cloning.” Note that communication deviated early within this round of the game to “hair transplant” and eventually a “fire hazard.”

Table 3: Potential questions to ask during de-brief of the communication icebreaker activity.

De-brief Discussion Questions
What did you find most challenging about this activity?
Which rounds were the most challenging? Why?
What would improve your ability to interpret your classmate's information?
Multiple terms are used within media (show examples)- how could a misinterpretation of this term alter public perception?

Assessing the activity

Both formative and summative assessment can be used to determine effectiveness of this activity. Formative assessment can be accomplished during the game to assess student engagement, enjoyment, and terminology knowledge. For example, to assess engagement observe student groups when they are discussing the completed whiteboard cards at the end of each round. Is more than one unique voice being shared within the group? Are students interacting within the group? Enjoyment can be assessed by observing student behaviors. Are students laughing? Are the student groups quiet and appear disengaged? Terminology knowledge can be assessed by observing the success of each round. Are any groups having difficulties with terms? Were any groups unsuccessful in completing the round with the same term they started with? Summative assessment can be useful in determining the level of challenge as well as terminology knowledge. If all groups were able to complete their round successfully, this could be an opportunity to change future terms to make them more challenging. Alternatively, if groups struggled to complete the rounds successfully, there is an opportunity to understand the reason. I use the discussion questions (Table 3) to understand whether the difficulty was due to issues illustrating or unfamiliarity with the term. Given this game is used as an icebreaker on the first day of class, it is possible they are not completely comfortable with advanced terms. If most advanced rounds are unsuccessful, consider altering terms to allow for a better balance of success for students. Alternatively, prepare discussions to focus around the major areas of struggle. For example, if students report difficulty in finding ways to illustrate, discussions may focus on the importance of context (see discussion below).

Discussion

Potential modifications

One advantage of this activity is that it is modifiable in multiple ways.

- Group sizes: I use this with groups of 5-6 students. I would not recommend using this activity for groups less than five. While you can increase group size, realize the overall time to complete a round will increase.
- Round length: I usually provide 1 minute per person as the cards are being filled out. If I notice that groups are finishing quickly (especially for the terminology writing rounds), I will shorten to 30 seconds. You can adjust this to longer or shorter intervals, based on cues from the students. Please make sure to clearly communicate time limits with the students.
- Number of rounds: I usually conduct three rounds with increasingly challenging terminology. That said, the number of rounds can be increased or decreased to suit your class's needs.
- Vocabulary: The terms can be customized to accommodate both introductory and advanced learners. Moreover, you can adapt discipline-specific terms. While this activity was used as an icebreaker within the course, it could be adapted into a learning tool prior to course assessments. This would give a chance for students to determine whether they recognize and understand key terms prior to a test or quiz.
- Laboratory vs. lecture environment: While this activity was used within a laboratory course environment, it could be amended to a lecture course environment, especially if students are able to re-arrange into groups within the room. Students must be close enough in proximity to pass the cards and have a table or flat surface available to spread the cards out at the end of each round.

Encouraging intra-group communication and metacognitive skills

There are numerous opportunities to generate student benefit in an icebreaker activity. For example, building "soft skills," which include collaboration and communication, has gained increasing importance (Lucs, 2014). To foster communication within groups, encourage students to explain their individual responses. This is particularly useful if the chain of communication breaks, and the term is modified during the round. This would also allow for multiple unique voices to be heard within the group.

Student reflection through metacognition has also been associated with improved learning outcomes in biology (Stanton et al., 2015). This activity may surprise students and provide an opportunity for students to critically assess why certain aspects of the game are more challenging. For example, students may find that interpreting a drawing is more challenging than illustrating a term. This could promote a conversation regarding how context is important when understanding scientific information. Discussion elements such as figure legends or clear references within scientific writing to define figures can provide key information for understanding what is being shown. Moreover, a discussion regarding the increasing challenge of describing terms with complexity can also be focused on. Why might it be more challenging to illustrate "CRISPR" rather than "DNA"? This could foster discussion of background information needed to adequately understand or recognize a term, which could lead into a group discussion on public literacy and science.

Connecting discussion to public literacy and media

Biological literacy is essential for disseminating discipline-specific information in a manner that can be understood by individuals within the public. This is particularly important for topics that may influence public policy (Klymkowsky et al., 2003). Students have seen biological terms used through social media and news networks. As an additional discussion activity, titles from magazines or news articles that integrate the "challenging" terms used in the game could be presented to the class. Students could then reflect on how an individual who does not have a background in biology may find difficulty in understanding that topic. Moreover, a discussion as to whether proper context is given in these articles could be addressed to parallel the discussion of context within the game.

Humor and classroom comfort

One other advantage of this activity is that it integrates humor within the classroom. Interjecting humor into a science course has been shown to contribute to an overall positive atmosphere (Berge, 2017).When students are comparing cards after a completed round, there is an opportunity to find humor in the illustrations, especially if the round is not successful. You can encourage students to embrace their "mistakes" by having groups select the funniest response to share with the class. This turns a situation with negative connotation (not producing the "right" answer) into a positive (finding humor in the process). Moreover, this is a learning opportunity- a chance for students to discuss why generating that response may have been difficult. We have anecdotally seen students who may feel embarrassment over their drawing receive encouragement from classmates within their group. Encouragement can bridge relationships, enabling students to become more comfortable around their classmates. Moreover, this can be an opportunity to discuss how science is often a process of learning through challenge, and that students may face challenges together (especially in the lab!). This further builds a sense of community and can provide a sense of belonging early in the laboratory course.

Concluding remarks

Overall, this icebreaker activity has provided a valuable opportunity to emphasize the challenges of communication while also fostering student interaction among students. While research has suggested that students have mixed opinions on icebreakers, we have observed intragroup engagement, laughter, and productive discussions suggesting an overall positive experience. Moreover, the customizable nature of this game creates a unique opportunity for it to be applied beyond my classroom, and in different biological disciplines where students of all levels can benefit.

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Editorial

ACUBE has a rich history of enhancing biology education through innovative research, curriculum development, and instructional methodologies that actively engage students, either in or outside the classroom. Over the years the ACUBE conferences have generated and stimulated enthusiastic thought provoking conversations between colleagues from around the world. Some ACUBE members have received national recognition for their work, something which ACUBE can be very proud of.

One of those recognized is Jason R. Wiles, Fellow of the American Association for the Advancement of Science (AAAS). Following my call earlier this year for a special edition I was not surprised that one of Jason's students, Elijah Carter, rose to the occasion. The following papers and testimonials speak about the large impact Jason has on biology education.

It is with great pleasure that we present this special issue of *Bioscene* in honor of Dr. Jason R. Wiles, whose outstanding contributions to biology education research and mentorship have shaped the careers of many faculty, post-docs, and students. Over the years, Jason has exemplified the best of what it means to be a scholar-teacher: rigorous in his inquiry, generous in his support of others, and unwavering in his dedication to improving the undergraduate experience in the biological sciences.

As a biology professor at Syracuse University, Jason has built a research program that explores how students make sense of biological ideas, how instructors can design learning experiences that foster deep understanding, and how to provide support for students from diverse backgrounds. His lab has served not only as a site of scholarly output, but as a community of learners. Current and former members of the Wiles Lab have contributed to this issue with articles and letters of gratitude, attesting to the ripple-effects of his influence.

I myself arrived in Jason's lab at a time when I had found myself in need of a new home for my graduate education; the fit with my first PhD advisor had grown untenable, and I was seeking a place where I could engage in meaningful teaching-oriented research while still grounding my work in biology. Joining Jason's laboratory introduced me to the rich and rewarding field of discipline-based education research. Under his mentorship, I learned to ask questions not just about "what happens" in the classroom, but "why" and "how" students make sense of scientific concepts. I learned to value the iterative process of designing instruction, gathering evidence, reflecting, and refining.

One of the most transformative aspects of his mentorship was his encouragement that I consider a PhD in college science teaching — an idea that, at the time, seemed both ambitious and unfamiliar to me. But Jason's confidence in my potential, and his commitment to helping me chart a path forward, gave me the courage to pursue that trajectory. Throughout my early career, he has continued to provide help and encouragement. Today, I am grateful to say that I have built a successful academic career in science teaching and learning, and that journey is inseparable from Jason's support, guidance, and belief in me.

This issue of Bioscene therefore stands not only as a collection of strong scholarly contributions from the Wiles Lab community, but also as a tribute to the mentoring, leadership, and collaborative spirit that Jason fosters. It celebrates the scholarship of biology education, the connections among mentor and mentee, and the shared commitment to improving teaching and learning in the biological sciences.

We hope that readers of this issue will find inspiration in the articles that follow, recognize the breadth of Jason's impact, and appreciate how one thoughtful mentor and research-teacher can help catalyze many others to become teachers, scholars, and change-makers.

Thank you, Jason, for your extraordinary work. May this issue reflect the gratitude of your many colleagues and former students — and may it help carry forward your legacy of excellence in biology education research.

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Stopgap to cyber savior: The impact of Peer-Led Team Learning toward mitigating barriers to STEM achievement

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Abstract

Inequity in degree attainment in Science, Technology, Engineering, and Mathematics (STEM) fields has been studied for decades, yet groups that have been excluded across STEM disciplines, such as women, first-generation college students, and members of certain racial and ethnic groups, have continued to earn a disproportionately lower percentage of STEM bachelor's degrees in comparison to their general representation in the United States. These inequities are in part due to the often cold and uninviting cultures and structures they encounter in STEM disciplines, which can lead to challenges such as imposter syndrome, stereotype threat, and lower levels of identification with science. Many of the factors contributing to these challenges have been successfully mitigated in educational environments employing Peer-Led Team Learning (PLTL), an active learning pedagogy that has been associated with long-term benefits leading to student achievement and retention when implemented in introductory STEM courses. Based on a decade of research, we suggest that PLTL could promote diversity, equity, and inclusion (DEI) in STEM for underserved groups, while leading to better outcomes for students from all backgrounds and without explicitly or exclusively being a DEI program, by combating imposter syndrome and stereotype threat and by strengthening science identity.

Keywords: Peer-Led Team Learning, Imposter Syndrome, Science Identity, Stereotype Threat, women, first-generation college students, underserved minoritized (URM) groups, STEM Degree Attainment, Inclusive Teaching.

Inequities in STEM Degree Attainment

Inequity in Science, Technology, Engineering, and Mathematics (STEM) degree attainment has been studied for decades, yet students from minoritized groups continue to earn a disproportionately lower percentage of STEM bachelor's degrees in comparison to their general representation in the United States (Palid et al., 2023; Irwin et al., 2021). For example, students from underserved minoritized (URM) groups – Hispanic, Black, and American Indian or Alaska Native – earned 26% of bachelor's degrees despite making up 37% of the U.S.'s college age population (The National Science Foundation [NSF], 2023). First-generation college students disproportionately identify as URM students, and 9% percent of first-generation college students complete college with a STEM degree as compared to 15% of continuing generation college students (Bettencourt et al, 2020). And while gender parity in STEM degree attainment has been reached in some STEM disciplines regardless of race or ethnicity, there is scant information on STEM degree attainment for gender non-conforming or non-binary students, and women only earn 25%, 24%, and 19% of bachelor's degrees in mathematical/computer sciences, physics, and engineering, respectively (NSF, 2023).

These observed inequities in STEM degree attainment are largely due to a wide range of factors at the societal and institutional level (London et al., 2011), as opposed to lack of ability or interest at the individual level. For example, the structure and culture of STEM environments can be cold and unwelcoming to students from minoritized groups, which can make it difficult for them to feel as though they belong. The threat to belonging is further compounded by the lack of shared-identity STEM role models for minoritized groups, and the underlying stereotypes upon which exclusive STEM cultures have been built.

Herein, we review research showing that without a sense of belonging (i.e., alienation) students can experience feelings of imposterism, stereotype threat, and/or weak identification with science, any of which can have negativeconsequences for persistence in STEM majors. Understanding these socio-psychological barriers, and what we as instructors can do to mitigate them, can help us support diversity, equity, and inclusion (DEI) in STEM for underserved groups. We also suggest that the active learning pedagogical strategy known as Peer-Led Team Learning (PLTL) could promote DEI in STEM, without explicitly nor exclusively being a DEI program, by acting as a buffer to these psychosocial barriers while improving outcomes for students from all backgrounds. Lastly, we provide a list of resources for academics who are interested in starting and sustaining a PLTL program at their home institution.

Psychosocial Barriers to STEM Degree Attainment

Imposterism (commonly known as imposter phenomenon or imposter syndrome) is characterized by an internalized feeling of incompetence and not belonging in a particular group despite having significant achievements and accomplishments (Clance, 1985). Students who experience imposterism view themselves as less capable than their peers and have trouble internalizing their successes, attributing their competence to luck, good fortune, or some other external cause (Lane, 2015). They believe they have somehow deceived others with regards to their intellect; feel a sense of fraudulence, phoniness, or inauthenticity; and fear that others will discover their perceived lack of competence (Clance & Imes, 1978; Lane, 2015). Imposterism can decrease classroom engagement, discourage students from attending class, increase thoughts of dropping out, and contribute to lower grades in STEM courses (Canning et al., 2020).

Although all students may experience imposter feelings to some degree, imposterism is more prevalent among women and URM students (Brauer & Proyer, 2017; Bravata et al., 2020). Similarly, first-generation college students are more at risk of impostor syndrome than continuing-generation students when in competitive classroom environments, like large-enrollment lecture-based courses (Canning et al., 2020).

The internalized feeling of not belonging that is associated with imposterism is often confirmed by actual feedback from the learning environment when the beliefs and behaviors of others perpetuate negative stereotypes about a particular group. To illustrate this concept:

- A math instructor who infrequently calls on women students during class despite women raising their hands as frequently as men perpetuates the biased stereotype that women are not as good at math.
- White students who choose to complete small group work with other White students instead of the Black student sitting nearest to them might perpetuate perceived, prejudiced stereotypes about Black students.
- An academic advisor who recommends a first-generation college student enroll in introductory physics despite them having successfully completed AP physics in high school perpetuates the unfair stereotype that first-generation college students are underprepared academically.

When confronted with such stereotypes, students are at risk of experiencing stereotype threat – a type of social identity threat that occurs when a student perceives being at risk of conforming to a negative stereotype about a social group to which they belong (Steele & Aronson, 1995). The fear of being devalued and conforming to negative stereotypes can impair performance on academic tasks, cause students to feel they must overcompensate to combat the stereotype and ultimately cause students to disidentify with the STEM fields (Drury et al., 2011; Harackiewicz et al., 2014; Murphy et al., 2007).

Stereotype threat can be triggered in members of any identity group that experiences negative stereotypes regarding their performance in a particular setting. Therefore, the harmful stereotypes that dictate who does and does not belong in STEM spaces create a culture where woman, URM students, and/or a first-generation college students are at greater risk of experiencing stereotype threat than students who fit the traditional representation of a scientist.

Imposter syndrome and stereotype threat could contribute to the rejection of a science identity and the attrition of well-qualified students from STEM majors. Science identity, the extent to which one relates to science (Carlone & Johnson, 2007), is important for STEM students because students who have a strong science identity tend to persist in STEM majors longer than those who have a weak science identity (Chang et al., 2011). In forming a science identity, a student must decide the degree to which their personal and social identities align with (1) their perception of who and what a scientist is and (2) their perception of what society believes a scientist to be (Carlone & Johnson, 2007).

Scientists are often portrayed as smart, socially awkward, or work-obsessed men of White or Asian descent, making it particularly challenging for any student who doesn't fit that description to identify as a scientist (Starr, 2018). Sure enough, science identity tends to be low among undergraduate students, especially for women and URM groups (Hazari et al., 2013; Robinson et al., 2018; Schmid & Wiles, 2022). Research exploring the science identities of first-generation college students is scant but suggests that first-generation college students may face several challenges to forming a strong science identity, such as low self-efficacy, poor academic preparation, or underrepresentation in STEM majors (Chen et al., 2021; Harackiewicz et al., 2014; Peteet et al., 2015).

Ways to Combat Psychosocial Barriers to STEM Degree Attainment

There are several ways that instructors can combat psychosocial barriers to STEM degree attainment. Perhaps the most obvious method is to use inclusive classroom practices, policies, and interventions that foster a sense of belonging for all students, regardless of their personal and social identities. The idea that a bolstered sense of belonging can act as a buffer against the negative effects of imposterism, stereotype threat, and weak identification with science are backed in research. For example, women's beliefs that they belong in STEM are one of the most robust predictors of their intent to persist in STEM (Lewis et al., 2017). Similarly, sense of belonging has been negatively correlated with imposterism in undergraduate URM students (Peteet et al., 2015).

Another way instructors can combat psychosocial barriers is by using classroom practices, policies, and interventions that promote self-efficacy. Self-efficacy is a student's confidence in their ability to successfully complete a specific (in this case science-related) task; it has been linked to interest in STEM, performance in STEM-related majors, and intention to pursue a STEM career (Tao & Gloria, 2019). Students who identify strongly with imposter characteristics tend to have a lower self-efficacy (Jöstl et al., 2012; Tao & Gloria, 2019). Similarly, students who have high self-efficacy tend to identify with science more readily than those who have low self-efficacy (Robinson et al., 2018).

Active learning in general has been shown to narrow gaps for URM populations (Theobald et al., 2020), particularly those that foster collaborative learning environments as opposed to competitive learning environments. Collaborative learning environments emphasize working together to solve problems and prioritize open communication. Inquiry-based activities where students work in collaborative groups have a significant impact on students' science identity and self-efficacy, especially URM and first-generation college students (Wilczek et al., 2022). On the other hand, competitive learning environments encourage students to gauge their own competence by comparing themselves to others (Canning et al., 2020). Comparing oneself to others can cause students to view themselves in a negative light, so environments like these can be detrimental for students who are already prone to negative self-thoughts (like those suffering from imposterism). For students who are experiencing stereotype threat, competition can impair their performance by redirecting their attention from the task and hand to their concern about conforming to a stereotype (Steele & Aronson, 1995). Competitive classrooms can also make it difficult for students who value teamwork, collaboration, and the sharing of perspectives to feel that their own personal values are in line with that of the STEM field as a whole, thus posing a threat to their science identity.

Finally, role models can combat psychosocial barriers. The main criteria for someone to be considered a role model are they must be perceived to be highly competent in their domain, and they must provide inspiration to others (Marx & Ko, 2012). Therefore, there are many individuals who can serve as role models for undergraduate STEM students, including STEM professionals, faculty members, graduate teaching assistants, and even advanced undergraduate students. Students who are experiencing stereotype threat benefit most when exposed to a role model with whom they share an identity (e.g., gender identity, racial identity, ethnic identity) or with whom they share attributes (e.g. interests, experiences, backgrounds; Marx & Ko, 2012). Exposure to shared identity role models has been associated with strengthened science identities, increased science self-efficacy, and protection against stereotype threat for women and URM students (Marx & Ko, 2012; Stout et al., 2011; Young et al., 2013). Increasing the number of shared identity role models in STEM can pose a challenge because personal and social identities are often immutable characteristics, and the stereotyped groups tend to also be the groups that are underrepresented. Furthermore, it is important not to unduly encumber members of underrepresented groups with the additional burden of serving as role models simply because of their membership in said group. Finding and exposing students to existing examples of potential role models with shared attributes may be more feasible, especially considering the shared attributes don't have to be domain specific so long as they create a sense of similarity and relatability between the perceiver and the role model (Marx & Ko, 2012).

PLTL: A Potential Buffer Against Psychosocial Barriers

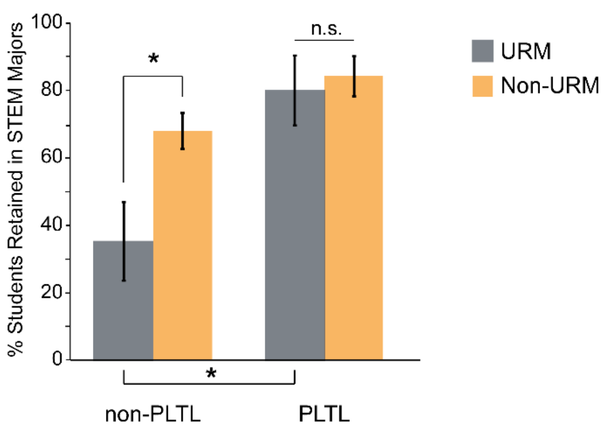
At Syracuse University, we have been implementing an active learning pedagogical model known as Peer-Led Team Learning (PLTL) in the large-enrollment introductory biology course for over a decade. During PLTL sessions, also called workshops, students meet in small groups and work collaboratively to solve problem sets that are related to a course they are taking together. Unlike the older pedagogical model known as Team Based Learning, in which the course instructor facilitates teams of students who are all taking the course the instructor is teaching, PLTL teams are guided by a peer leader, an advanced near-peer student who succeeded in the course during a previous semester and who could serve as a positive role model. Peer leaders receive training in collaborative learning techniques, so they can promote discussion and problem solving among their groups. Students meet weekly with the same group and peer leader to foster sense of belonging within the learning community. PLTL participation has been associated with increases in self-efficacy (Mills et al., 2020). In our context, we have repeatedly seen positive impacts for students across all background, including traditionally well-represented and non-excluded groups, but particularly for URM students, women, and first-generation college students.

We first implemented our PLTL program in response to an institutional curriculum revision, which included important programmatic improvements for biology majors, but which also made the lab component optional in the second semester of the introductory biology sequence. We found that participating in PLTL was a successful stopgap measure, in that students who opted out of lab but participated in PLTL performed on concept-based exams at levels equivalent to those who enrolled in lab (Snyder et al., 2015), and significantly higher than those who did not participate in PLTL. As this study involved students in the second semester of the sequence, we were able to determine whether self-selection based on prior achievement was a factor. Student grades in the previous semester were not predictive of participation in PLTL, nor were high school GPA nor SAT/ACT scores. In our population of students, PLTL participation was also associated with higher achievement across all groups, including traditionally well-represented groups. Simultaneously, achievement gaps were greatly reduced between URM and non-URM students, in that the percentage of URM students who earned Ds, Fs or Withdrew (DFW) from the course was significantly lower for those who participated in PLTL (Snyder et al., 2016). PLTL also has important long-term impacts on retention. Women, URM students, and first-generation college students who participated in PLTL during our introductory biology course were retained in their STEM majors four years later at significantly higher rates than those who did not participate (Maxwell et al., 2023; Sloane et al., 2021; Figure 1).

The association we see between PLTL participation and underserved student retention might be a result of PLTL combating imposterism.

PLTL could combat imposterism by increasing students' self-efficacy and providing a collaborative learning environment in an otherwise competitive, large-enrollment course. In fact, women in our population of introductory biology students experience greater feelings of imposter than men and attending PLTL sessions was associated with decreased feelings of imposterism (Maxwell et al., 2023).

Figure 1. Four-year retention in STEM majors of URM and non-URM students with and without PLTL. Error bars represent standard error of percent. Asterisks indicate significance of chi-square tests at p<0.05. Reprinted with permission from Sloane et al. (2021).



PLTL may also support underserved groups by providing students with near-peer role models. Peer leaders are likely perceived as competent and inspiring because they succeeded in the course during a previous semester and thus meet the criteria for being a role model. Additionally, students may share more attributes (and perhaps more identities) with their peer leader than the course instructor or graduate teaching assistant and therefore may view them as more relatable (Winterton et al., 2020). This relationship could explain the positive impact PLTL has on the academic achievement and retention of underserved students. We have, in fact, found in our context that students who relate to their peer leader tend to have higher perceived learning gains and have higher course achievement than those who do not relate to their peer leader (Winterton et al., 2020). Most recently, peer leaders have been shown to be better at assessing their students' learning gains and achievement than the students themselves, potentially positioning peer leaders as early warning detectors to identify students who may be struggling. (Winterton, Dunk, & Wiles, 2025 [in review at this journal]).

Variations of PLTL Are Also Successful

We are invested in PLTL as a way to support the success of minoritized groups in our department, and we have observed positive results even through extraordinarily challenging times. During the COVID-19 pandemic, we transitioned from PLTL to cyber Peer-Led Team Learning (cPLTL), a relatively new variation of PLTL in which the workshops occur in a synchronous online setting. It has been suggested that cPLTL might create opportunities for a more diverse student body to engage in active learning by creating more flexible scheduling and attendance options for students and peer leaders, and by removing the need for a physical meeting space (Mauser et al., 2011).

As we hypothesized, cPLTL participation during the COVID-19 pandemic was associated with greater academic achievement and retention, particularly for women, URM students, and first-generation college students (Maxwell & Wiles, 2022). Additionally, the majority of cPLTL students who responded to an online survey agreed that participating in the cPLTL improved their self-confidence, helped them form relationships with other students in the course, and made them feel included in the course; all of which could protect them against imposterism and stereotype threat while making it easier for them to identify as scientists. Additionally, a majority of students reported that they received positive feedback from their peer leaders, another factor that supports the formation of a strong science identity (Park et al., 2018).

Resources for Starting and Sustaining a PLTL Program

There is a growing, international, and interdisciplinary community of science educators sharing vetted materials to help start and sustain a PLTL program (Table 1). The PLTL International Society (PLTLIS) has a plethora of useful information on their website, including tips for getting a PLTL program started, resources for PL training, workshop modules for different

Table 1. Resources for starting and sustaining a PLTL program.

Resource	Description
Peer-Led Team Learning International Society Website (https://pltlis.org/)	PLTLIS offers vetted resources for starting PLTL program, peer leader training, and workshop modules, and more.
Gosser, D. K., Cracolice, M. S., Kampmeier, J. A., Roth, V., & Strozak, V. S. (2000). *Peer-Led Team Learning: A Guidebook*. Pearson College Division.	This guidebook explains the theory behind PLTL, offers suggestions for successful implementation, discusses how to evaluate the success of the program, and addresses frequently asked questions.
Roth, V., Goldstein, E., & Marcus, G. (2001). *Peer-Led Team Learning: A guidebook for team leaders*. Prentice Hall.	This guidebook is designed for peer leaders. It explains background and advice for effective leading, describes relative pedagogical topics like learning theory, group dynamics, and conflict resolution, and provides additional readings in related areas.

disciplines, information about administration and organization, and examples of effective methods of program evaluation. *Peer-Led Team Learning: A Guidebook* by Gosser and colleagues (2000) is a useful guide for aspiring practitioners to learn how to implement and evaluate the success of a PLTL program. Similarly, *Peer-Led Team Learning: A guidebook for team leaders* by Roth and colleagues (2001) is available as a training manual for peer leaders.

Conclusions

Despite decades of research, and some degree of positive progress, there are still inequities in STEM degree attainment for minoritized groups like women, URM students, and first-generation college students. These inequities are in part due to challenges such as imposter syndrome, stereotype threat, and weak identification with science, which are compounded by a lack of sense of belonging, particularly in non-inclusive environments. Here, we provide a review of research indicating that PLTL and its variations could provide a buffer against these psychosocial barriers by bolstering students' sense of belonging and improving their self-efficacy in a collaborative learning environment with near-peer role models. We are invested in PLTL as a way to promote achievement, recruitment, and retention in STEM for all groups, and contributing to diversity, equity, and inclusion.

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Peer-Led Team Learning (PLTL) May Provide Early Detection for Student Success or Challenges in Introductory Biology

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Abstract

Peer-Led Team Learning (PLTL), an active learning strategy involving students working closely with a peer leader, often as a supplement to high-enrollment introductory undergraduate courses, has been well documented as a beneficial strategy for improving student outcomes. However, little is known about how students and their peer leaders view and assess student learning. For this study, we sought to explore this by comparing final course grades in a mixed-majors Introductory Biology course alongside the Self-Assessment of Learning Gains (SALG) survey instrument. These surveys were completed by the students themselves, in addition to their peer leader completing the survey to assess the learning gains of the students they had been leading. We found that peer leaders are able to accurately assess students' learning gains, which is predictive of their final grade in the Introductory Biology course. Students were comparatively less capable of perceiving their own learning gains, and there was no correlation with the student's self-assessment of learning gains and their final course grade. These findings suggest that peer leaders hold great potential concerning student retention, and that – with proper training – peer leaders may be able to detect when a student is excelling or when they need to be connected to more resources to achieve academic success.

Keywords: Introductory Biology, Peer Led Team Learning, Learning Gains, Retention

Peer-Led Team Learning May Provide Early Detection for Student Success or Challenges in Introductory Biology

Peer-Led Team Learning (PLTL) is an active learning technique often used to supplement large introductory STEM courses. Students enrolled in PLTL attend collaborative problem-solving workshops led by fellow students who have recently and successfully completed the same course (the "peer leader"; Gosser & Roth, 1998). Participation in the PLTL program has been associated with a wide range of benefits for students as well as the peer leaders facilitating the group (Snyder & Wiles, 2015; Snyder et al., 2016; Sloane et al., 2021, Maxwell & Wiles, 2022; Maxwell et al., 2023). The PLTL model has successfully been replicated in a wide range of STEM and computer science courses across multiple types of institutions (Streitweiser & Light, 2010; Quitadamo et al., 2009; Wilson &Varma-Nelson, 2016). PLTL differs from other active learning strategies in that there are no grade values assigned to the problem sets, and the workshop and discussion are facilitated by the peer leader rather than faculty members. This environment allows for unique interactions between peer leaders and the students which contribute to the success and versatility of PLTL (Eberlein et al., 2008).

The PLTL environment enriches the interactions between the students and the peer leaders with students finding peer leaders to be relatable and often viewing them as role models (Winterton, Dunk, & Wiles, 2020). This study seeks to consider these interactions toward illuminating the impact an attentive peer leader may have on the student's perceptions of learning in the course as well as whether peer leaders may be able to accurately assess student learning gains in relation to achievement in the course.

The Role of the Peer Leader

The role of the peer leader has been described in the literature as a fellow learner who engages the group in problem-solving activities, facilitates discussion of scientific concepts and ideas, and helps students to develop deeper conceptual understanding of scientific topics, rather than simply providing answers of problem sets to students (Chan & Bauer, 2015; Gafney & Varma-

Nelson, 2008; Streitwieser & Light, 2010; Gosser et al., 2001). Peer leaders have also been characterized in the literature as open and friendly resources for students who might otherwise feel intimidated by professors (Micari et al., 2005). Effective peer leaders are able to moderate the environment of STEM courses by providing meaningful interactions where questions are welcomed in support of learning (White et al., 2012). Maintaining this environment is crucial, as it has been shown that, particularly in college level science courses, participation and engagement in active learning strategies will result in student's learning more than in a passive environment such as traditional lectures (Crouch & Mazur, 2001; Freeman et al., 2014).

In addition to acting as a fellow learner, peer leaders also face the difficult challenges of guiding students, keeping them engaged, and helping them to actively participate. It may become challenging to keep students engaged and on-task, because if students do not view the material in the PLTL workshops as directly related to assessments in the main course, students are not likely to actively participate (Mottley & Roth, 2013). A strategy for overcoming this resistance may be to form unique bonds with the students that professors would not be able to form in a large lecture hall. Peer leaders have reported initiating conversations in workshops by telling students more about themselves and found that sharing personal details gets the students to be more open and feel more comfortable within the group (Streitweiser and Light, 2010). They also found that, while it can sometimes be challenging, peer leaders can be well attuned to the needs of their students and often find deep satisfaction in helping others.

PLTL Environment and Dynamics

During the weekly PLTL workshop sessions, students and their peer leader encounter problem sets that require different knowledge sets, application of skills, and critical thinking. These modules are intentionally designed for groupwork, requiring the students to communicate with one another and their peer leader to form novel solutions to new scenarios (Eberlein et al., 2008). This collaboration highlights students' strengths and weaknesses and allows the peer leader to differentiate between topics that need improvement and content that students have already mastered. Actively engaging with the student while discussing, evaluating, and assessing material positions the peer leader to directly observe learning and student growth from a perspective that most professors of large lecture courses would not have the opportunity to establish. Given the unique role of a peer leader, their interactions with students will likely influence the students' perceptions of the course as well as their self-perceived learning gains. Peer leaders often develop a close rapport with students, resulting in students viewing them as relatable, or even as a role model, which can positively influence students' final course grades and perceived learning gains (Winterton et al., 2020). Given the peer leader's responsibilities in a PLTL session and this unique bond with the students, it is reasonable that they may be cognizant of students' learning gains and needs. Peer leaders have the ability to relate to and support their students with personal experiences from when they were enrolled in the course, providing a unique vantage point into student learning (Winterton et al., 2020; Finn & Campisi, 2015). This suggests that in the comfortable environment, with heightened relatability and communication, peer leaders will have some sense of their students' learning needs. This could provide an avenue for the students to receive direct one-to-one help and guidance catered to their specific needs in a way that professors are often not able to provide.

It has been well documented that faculty-student interactions have an impact on student attitudes, persistence, and learning in a course (Christe, 2013). While peer leaders are not expected to be content experts or execute the same responsibilities as professors, they are a crucial component to the success of the PLTL model through their facilitation of the learning modules and support of the students. Peer leaders can play a powerful role in student persistence and retention in STEM through their unique interactions, relationships and understanding of their students (Sloane et al., 2021; Snyder et al., 2016; Winterton et al., 2020). In this study, we sought to understand the relationship between peer-leader perceived learning gains and course performance of undergraduates in a PLTL experience.

Materials and Methods

Under an IRB-approved protocol (Syracuse University IRB #14-313), students attending PLTL sessions associated with an introductory biology course were asked to complete a modified version of the Student Assessment of Learning Gains (SALG) survey (Winterton, 2018). The SALG survey indicates perceived learning gains across categories such as understanding, skills, attitude, integration of learning, the class overall, class activities, information about the class, and support for the student as an individual learner (Seymour et al., 2000), as well as areas outside of content mastery, such as enthusiasm for the material, integration of knowledge, and likelihood to pursue the subject after the completion of the current course. Herein, we focus only on those items directly related to learning gains.

The SALG survey was administered to peer leaders and active PLTL participants halfway through the semester. The results of the participating PLTL student's self-perceived learning gains were named "S-SALG". The peer leaders were also asked to fill out the SALG survey for each of their students to indicate their perceptions of each student's individual learning gains. These results were named "L-SALG". Only student-leader pairings where both parties completed 100% of the SALG survey were included in the analyses. A total of 35 peer groupings met these criteria; each group had a unique peer leader, and no groups had more than 5 students assigned to a given peer leader.

The lowest SALG score possible (i.e., a score of 1 for each item) was 25, while the highest SALG score possible (i.e., a score of 5 for each item) was 125. For comparison purposes, the average S-SALG score and the average L-SALG score within a given group were used to look for similarities and differences between leaders and students across groups and in comparison to student's final course grades.

Statistical analyses of the quantitative data collected from administering the SALG instrument to students were performed with SPSS version 24 and R 3.4.1. The summation of all SALG responses was used for analyses. Cronbach's alpha, a measure of internal consistency, was determined for students' SALG scores to verify that the SALG instrument was able to be used as a single measure of learning gains. Cronbach's alpha was found to be 0.98 (which is considered excellent), indicating that using the sum of SALG answers is a defensible measure of students' perceived learning gains.

A mixed-design Analysis of Variance (ANOVA) was conducted to determine: 1) if the average L-SALG scores differed across groups (Between-Subjects), 2) if SALG score estimates of individuals differed if they were reported by the student themselves versus the leader (Within-Subjects Scores), and 3) if the differences between L-SALG and S-SALG scores varied across groups (Within-Subjects Scores*Leader).

Additionally, Pearson's correlation coefficient was calculated for comparison of SALG results to student's final course grades in the Introductory Biology course. Two separate calculations were performed. The first used the average L-SALG score (as assessed by the peer leader for the students in their group) and compared this value to the average final course grade for the students in the group. The second calculation was a comparison of the student's own S-SALG score with their final course grade.

Results

When analyzing L-SALG and S-SALG scores, we found students and peer leaders did significantly differ in their assessments of the student's learning gains $F(1,113) = 24.1$, $p < .001$ as shown in Table 1

Further, the degree of this difference significantly differed by leader when comparing across all peer mentoring groups, $F(35,113) = 1.93$, $p = .005$, showing that in some groups, the L-SALG and S-SALG were in greater agreement than in others. There was also a significant difference found in L-SALG scores across the different peer-led groups, $F(35,113) = 1.57$, $p = .041$.

For each group, the average L-SALG score was compared to the student's final course average, showing a comparison of student's learning gains as assessed by peer leaders and final course grade achieved by the students.
($r = .393839$, $p=.01924$)

Table 1. Mixed-Design ANOVA table comparing paired S-SALG and L-SALG scores

Source	SS	Df	MS	*F*	*P*	partial η^2
Between-Subjects						
Leader	26291	35	751	1.57	.041	.326
Error	5424	113	480			
Within-Subjects						
Scores (Student v. Leader	11043	1	11043	24.1	.000	.176
Scores Leader	30872	35	882	1.93	.005	.374
Error	51686	113	457			

Figure 1. Comparison of L-SALG scores to student's final course grades.

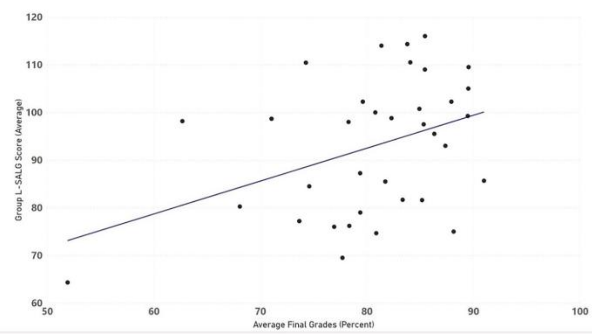
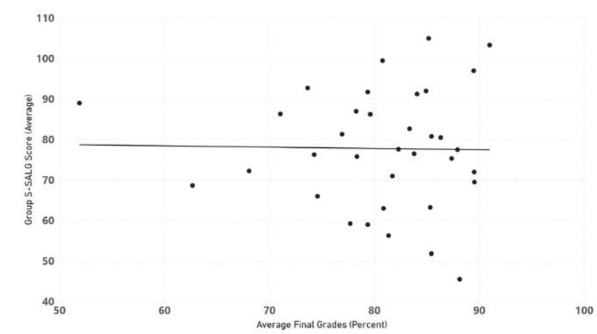


Figure 2. Comparison of S-SALG scores to student's final course grades.



The different learning gain measurements were also compared to the student's final course average. Fig 1 shows the peer leader reported SALG scores for each student in their group correlated with the student's final course grade in Introductory Biology (r = .393839, p=.01924). However, the student's SALG score and their own final course grades were not significantly correlated (r= -.047, p= .5657) as shown in Fig 2.

For each group, the average S-SALG score was compared to the student's final course average, showing a comparison of student's self-assessed learning gains and final course grade achieved by the student. (r = -.047, p= .5657).

Discussion

Our first finding supports the idea that the experience of each student and peer leader was unique, suggesting a varying degree of productive interactions during the semester. We also see that across the groups, some groups felt that they had learned more than others (*F*(35,113) = 1.57, (p =.041). Some factors that may have fluctuated across groups include the timing of the weekly meeting, the relative dedication of the students or peer leader, the efficacy of group dynamics, or perhaps that different groups or individuals may have believed they had higher innate abilities in the subject than others. When looking at only S-SALG results, it is important to consider that students are often not accurate in assessing their own learning gains (Porter, 2013; Deslauriers et al., 2019).

To explore the possibility of students' self-assessments of learning gains not being an accurate reflection of their ability to meet course objectives, we also looked at the L-SALG scores. These scores are the results of asking the peer leader to complete the SALG survey to rate the learning gains of each of their students. A comparison between S-SALG and L-SALG scores showed a significant difference between the responses of students and their respective peer leaders with regard to the students' learning gains (p=<.001). We found that, generally, peer leaders were assessing their student's learning gains higher than the students themselves. In 80% (28 out of 35) of PLTL groups, the peer leader reported higher average learning gains than the corresponding students within their group. PLTL is an active learning technique, so this finding aligns with previous research that students tend to underrate their learning when conveyed through active learning measures, even when course outcomes (final grade) are high (Deslauriers et al, 2019). PLTL can also offer a solution to addressing this discrepancy, if peer leaders routinely explain the purpose of active learning to students while completing the modules and share their own personal experiences with active learning. Peer leaders could also share the growth that they are observing with the students themselves, in the hopes that the students will recognize their own growth and learning that is taking place. Incorporating these interventions may help increase student course performance and lessen the resistance to active learning methods (Tharayil et al., 2018).

Further, student success and academic achievement is positively linked to student satisfaction in the course (Aung & Ye, 2016). This indicates that students who may have strong feelings of learning could still be passionate about the course content, and perhaps their final course grade is not a good measure of their satisfaction with the course or science content. We indeed found that the student's feeling of learning is independent of final course grade (p= .5657). Hence, there may be potential to target students whose marks in the course may be lower than expected and salvage their desire to pursue STEM by helping them to identify feelings of progress in learning, rather than disappointment regarding expected grades. Helping students to recognize their own learning gains through PLTL might motivate adoption of similar programs in other STEM courses and provide students with a support system of their peers who may be experiencing the same challenges.

Finally, our results indicate that while students may not accurately assess their own learning gains, peer leaders were accurate at reporting on student's learning gains as supported by final course grades. On average, the leader's assessment of their student's learning gains (L-SALG) was correlated with the student's final grade in the General Biology course (r=.39; p= .019). Peer leaders may therefore be an informative conduit between the two measures of final course grades and perceived learning gains and could be a stop gap for early detection of student success in the course. Given the successful implementation of PLTL across multiple institutions and a wide range of STEM disciplines (Streitweiser & Light, 2010), the current study highlights a new and unique way to utilize the existing role of the peer leader without changing any critical features of the program. It is also promising to see these results in a large enrollment mixed majors course such as this, showing that the peer leaders do not necessarily need to be the same major as their students to accurately assess their learning gains or aid in success. Because peer leaders are present and actively involved in the sessions and discussions every week, they have the unique vantage point of observing the changing thought processes for the students in their group. The potential of this tool and peer leader assessment should be explored as a resource for early detection of student success or obstacles within the larger biology course, as well as a means to identify the students who are excelling in the subject. These students could then be offered various opportunities within the department, particularly an invitation to become a peer leader in future semesters.

Conclusion

Our findings show that peer leaders have the potential to provide a powerful tool in assessing students' learning gains and course performance. Students themselves are relatively poor assessors of their own learning gains, particularly in active learning courses, but peer leaders have shown a greater ability to assess student learning and predict academic achievement. Therefore, in addition to the other established benefits of PLTL, we posit that peer leaders could potentially serve as an early detection system, identifying when students are struggling as well as when they are excelling.

These implications could profoundly impact student retention through earlier efforts to connect students with the resources necessary for them to succeed. The connection between the peer leader and their students should not be underestimated, and can provide insight into reshaping high enrollment courses. We therefore recommend integrating assessment techniques into the leadership training for peer leaders and opportunities to communicate about their perceptions of their students' learning. Peer leader training can be expanded to identify social cues of when the students are struggling or when they have mastered a concept. These signals will arise organically during the existing duties of the peer leader at each session: listening to the group discussion, contributing ideas when appropriate, and gauging students' sense of understanding. A focus on assessment and evaluation into the program seems a natural inclusion that can be readily added to peer leader training. Future research should include expanding this study to undergraduate teaching assistants and graduate teaching assistants to determine if this finding can be applied across roles in an instructional team, especially those closer to the student's own level of learning than the course professor.

Acknowledgements

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Differential Impacts of Family Income Background on GPA and STEM Retention among Undergraduate STEM Students Prior to STEM Intervention Program Implementation

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Abstract
Studies in the U.S. show that students from low-income backgrounds graduate with STEM degrees at lower rates than their higher income peers. Prior research attributes this disparity to factors such as academic under-preparedness, limited social and cultural capital, lower STEM identity, and a weaker sense of belonging. To address these challenges, institutions have implemented STEM Intervention Programs (SIPs) using a variety of targeted interventions. This retroactive study establishes a baseline understanding of how low-income and higher-income STEM students have historically performed in terms of graduation rates and cumulative GPA at a private, predominantly white institution (PWI) in the northeast United States prior to the implementation of an SIP designed to reduce disparities. Our results indicate that during this timeframe, STEM graduation rates for low-income and higher-income students at this institution were statistically identical, and GPA differences between low-income and higher-income STEM graduates were not significant. However, a larger percentage of low-income students took more than four years to complete their STEM degrees compared to their higher-income peers. These findings suggest that SIPs should focus on improving time to graduation for low-income students to enhance their overall success in STEM fields.

Keywords: STEM education, higher education, retention, low income, undergraduate, STEM intervention program, SIP

Introduction

The National Science Board (NSB) reported that more than 21 million students are enrolled in U.S. colleges and universities, and about 30% of these students are low-income and first-generation students (NSB, Science and Engineering Indicators, 2018). Engle and Tinto (2008) found that first-generation and low-income students are four times more likely to drop out of college compared to their peers who are neither first-generation nor low-income.

Post-secondary institutions in the United States face two main challenges in cultivating STEM talent (Chen, 2015). The first challenge is attracting a diverse group of undergraduates to pursue STEM majors. This remains a significant obstacle since few underrepresented minorities, women, and low-income students from disadvantaged backgrounds choose to study STEM disciplines in college (Chen, 2015; Castellanos, 2018; Meoli et al., 2024; Seidman, 2004). The second, and even greater, challenge is retaining these students in the STEM pipeline throughout their undergraduate years. Numerous studies have identified key barriers to persistence in STEM, including insufficient pre-college academic preparation for the challenges of STEM coursework, unsupportive social environments within STEM departments, and outdated teaching methods in introductory STEM courses that fail to inspire scientific inquiry (Chen, 2015; Morganson et al., 2015; Olson & Riordan, 2012; Provencher & Kassel, 2019). The National Academy of Sciences (2011) highlights critical areas requiring attention to reduce STEM attrition rates among low-income undergraduates, including student preparedness, access, motivation, and the academic and social support systems necessary for persistence in STEM (Kates, 2011). Specifically, researchers have identified academic socialization as a key predictor of student retention and persistence in STEM fields (Hunter et al., 2007).

To address these challenges with a coordinated and strategic approach, we developed the Strategic Undergraduate STEM Talent Acceleration INitiative (SUSTAIN) project.

The National Science Foundation (NSF) initially funded the project under its Scholarships in STEM (S-STEM) program. The NSF awards S-STEM grants to STEM Intervention Programs (SIP) that aim to improve the retention of low-income, academically talented students in STEM. These programs provide scholarships and implement evidence-based curricula that support student success. Each program tailors its approach based on the specific needs of its institution's student population.

Understanding these differences is essential so that institutional programs like SIPs can align their curricula with students' needs and measure improvements against historical trends. This retroactive study establishes a baseline understanding of how low-income STEM students have historically performed compared to higher-income STEM students in terms of graduation rates and cumulative GPA at a private, primarily white institution (PWI) in the northeastern United States before implementing SUSTAIN. The research question explored in this study is:

What are the historical trends in post-secondary achievement among low-income and high-income undergraduate STEM students who had been high achievers in secondary school?

We hypothesized that, in absence of an SIP, low-income students will have lower GPAs and graduation rates. Prior research indicates that socioeconomic status predicts GPA (Sharkness et al., 2010) and that low-income students across all majors graduate at lower rates than their higher-income peers (Cahalan et al., 2022; Engle & Tinto, 2008).

Methods

Data Collection

The study population comprised domestic students who matriculated as STEM majors in the College of Arts & Sciences (Table 1) at the university in 2014, 2015, and 2016 with a high school GPA greater than 3.0. This GPA threshold was the criterion for "high achieving" as specified by NSF's S-STEM requirements. These dates of matriculation were chosen to establish a baseline measure of student achievement before the implementation of the SUSTAIN SIP program at the study institution. The study population consists of 825 students, of whom, 281 (approximately 34%) were recipients of federal Pell grants, a common indicator of low-income status (Table 2). Background demographics and outcome data for this group were obtained in conjunction with the University's Office of Institutional Research and Assessment (OIRA) (Tables 2 & 3). It should be noted that the OIRA cannot distribute individual-level data including Pell status, so the researchers were provided only group-level data for this study.

A subset of the population who graduated with STEM degrees was sampled to explore differences in cumulative GPA between the groups. The graduating degrees expanded to

Table 1. Eligible Matriculating and Graduating Majors

Arts & Sciences STEM Majors (Matriculation)		All STEM Majors at the Institution (Graduation)	
Applied Mathematics	Earth Sciences	Applied Data Analytics	Environmental Geoscience
Applied Statistics	Environmental Geoscience	Applied Mathematics	Forensic Science
Biochemistry	Forensic Science	Applied Statistics	Geology
Biology	Geology	Biochemistry	Health and Exercise Science
Biotechnology	Mathematics	Biology	Information Management & Technology
Chemistry	Neuroscience	Biotechnology	Mathematics
Communication Science & Disorders	Physics	Chemistry	Neuroscience
	Statistics	Communication Science & Disorders	Nutrition Science
		Computer Science	Physics
		Earth Sciences	Statistics
		Engineering (any type)	

Table 2. Demographics of Students who started in a STEM Major in the College of Arts & Sciences			
	Total Sample n = 825 (%)	Non-Pell Recipients n = 544 (%)	Pell Recipients n = 281 (%)
Gender[1]			
Woman	545 (66.1)	347 (63.8)	198 (70.5)
Man	280 (33.9)	197 (36.2)	83 (29.5)
Race & Ethnicity[2]			
White	523 (63.4)	404 (74.3)	119 (42.3)
Black	75 (9.1)	36 (6.6)	39 (13.9)
Hispanic	103 (12.5)	40 (7.3)	63 (22.4)
Asian	80 (9.7)	36 (6.6)	44 (15.7)
Two or more races	31 (3.8)	20 (3.7)	11 (3.9)
Am. Indian/Haw/Pac Is	4 (0.5)	1 (0.2)	3 (1.1)
Unknown	9 (1.1)	7 (1.3)	2 (0.7)
Generation Status			
Continuing-Generation	554 (67.2)	452 (83.1)	102 (36.3)
First-Generation	271 (32.8)	92 (16.9)	179 (63.7)
GPA			
High School GPA	-	3.80	3.83
First Year College GPA	-	3.30	3.20
Matriculated Major[3]			
Applied Mathematics	8 (1.0)	4 (0.7)	4 (1.4)
Biochemistry	58 (7.0)	41 (7.5)	17 (6.0)
Biology	253 (30.7)	179 (32.9)	74 (26.3)
Biotechnology	26 (3.2)	17 (3.1)	9 (3.2)
Chemistry	43 (5.2)	22 (4.0)	21 (7.5)
Comm Sci & Disorders	41 (5.0)	30 (5.5)	11 (3.9)
Earth & Env Science	13 (1.6)	10 (1.8)	3 (1.1)
Forensic Science	81 (9.8)	54 (9.9)	27 (9.6)
Mathematics	60 (7.3)	42 (7.7)	18 (6.4)
Neuroscience	80 (9.7)	50 (9.2)	30 (10.7)
Physics	37 (4.5)	22 (4.0)	15 (5.3)
Pre-Med/Pre-Vet	125 (15.2)	73 (13.4)	52 (18.5)

include STEM degrees from any school or college at the institution. Table 1 lists the graduating degrees that are considered "STEM" for the purposes of this study. This group consists of 540 students (~33% Pell) and their demographics can be found in Table 3.

Data Analysis

The four-, five-, and six-year outcomes of students who started in a STEM major in the College of Arts & Sciences in 2014, 2015, and 2016 were compared by Pell status using two-population percentage z-scores. The outcomes included graduation in STEM, graduation in non-STEM, enrolled in STEM, enrolled in non-STEM, dropped out, and stopped out. "Stopped out" refers to students who left the institution and are confirmed to have returned at a later date. As this percentage of students is quite small (>1%), they have been excluded from all figures.

GPA was also compared between the 177 low- and 363 higher-income STEM graduates.

Table 3. Demographics of Students who graduated with any STEM Major at the Institution			
	Total Sample n = 540 (%)	**Non-Pell Recipients n = 363 (%)**	**Pell Recipients n = 177 (%)**
Gender[1]			
Woman	**355 (65.7)**	**234 (64.5)**	**121 (68.4)**
Man	**185 (34.3)**	**129 (35.5)**	**56 (31.6)**
Race & Ethnicity[2]			
White	**358 (66.3)**	**277 (76.3)**	**81 (45.8)**
Black	**47 (8.7)**	**24 (6.6)**	**23 (13.0)**
Hispanic	**63 (11.7)**	**24 (6.6)**	**39 (22.0)**
Asian	**47 (8.7)**	**21 (5.8)**	**26 (14.7)**
Two or more races	**19 (3.5)**	**12 (3.3)**	**7 (3.9)**
Am. Indian/Haw/Pac Is	**2 (0.4)**	**1 (0.3)**	**1 (0.6)**
Unknown	**4 (0.7)**	**4 (1.1)**	**-**
Generation Status			
Continuing-Generation	**380 (70.4)**	**308 (84.8)**	**72 (40.7)**
First-Generation	**160 (29.6)**	**55 (15.2)**	**105 (59.3)**
GPA			
High School GPA	**-**	**3.86**	**3.85**
First Year College GPA	**-**	**3.39**	**3.38**
Graduate Major[3]			
Applied Mathematics	**15 (2.8)**	**11 (3.0)**	**4 (2.3)**
Biochemistry	**40 (7.4)**	**27 (7.4)**	**13 (7.3)**
Biology	**196 (36.3)**	**131 (36.1)**	**65 (36.7)**
Biotechnology	**28 (5.2)**	**23 (6.3)**	**5 (2.8)**
Chemistry	**32 (5.9)**	**22 (6.1)**	**10 (5.6)**
Comm Sci & Disorders	**24 (4.4)**	**16 (4.4)**	**8 (4.5)**
Computer Science	**2 (0.4)**	**2 (0.6)**	**-**
Earth & Env Science	**8 (1.5)**	**6 (1.7)**	**2 (1.1)**
Engineering	**44 (8.1)**	**26 (7.2)**	**18 (10.2)**
Forensic Science	**36 (6.7)**	**22 (6.1)**	**14 (7.9)**
Health & Exercise Science	**8 (1.5)**	**3 (0.8)**	**5 (2.8)**
Info Mgmt & Technology	**14 (2.6)**	**5 (1.4)**	**9 (5.1)**
Mathematics	**23 (4.3)**	**16 (4.4)**	**7 (4.0)**
Neuroscience	**45 (8.3)**	**33 (9.1)**	**12 (6.8)**
Nutrition Science	**10 (1.9)**	**7 (1.9)**	**3 (1.7)**
Physics	**13 (2.4)**	**11 (3.0)**	**2 (1.1)**
Systems & Information Sci	**2 (0.4)**	**2 (0.6)**	**-**

Notes: [1]"Gender" is the gender of record as reported by the institution from students' legal documentation. [2]Race/ethnicity was self-reported to the institution. If "Hispanic" was indicated at any point, they were not included in any other race/ethnicity category. [3]Students who graduated with two or more majors were counted as their first listed STEM major.

Mean cumulative GPAs were compared using independent t-tests. These GPAs are from the end of their first through fourth spring semesters. Since the students are from three separate matriculation years, GPA data was grouped by students' academic years rather than the actual year the data were collected. Since these data were grouped by Pell status, only group-level data were provided to the researchers by the OIR, which limited the types of analyses that could be performed.

Results

STEM Retention

The 4-year graduation rate in STEM was 62.7% for higher-income (non-Pell) students and 55.9% for Pell students (Figure 1). This difference was statistically significant, (z = 1.893, p = .029). A marginally greater percentage of higher income (non-Pell) students switched to a non-STEM major and graduated by the end of four academic years, (z = 1.330, p = .092) (Figure 1). A significantly larger percentage of Pell students were still enrolled in STEM at the end of their fourth year than non-Pell students, (9.3% vs 4.2%, respectively, z = -2.976, p = .002) (Figure 1). In the same trend, there was also a significantly larger percentage of Pell students who had switched out of STEM and who were still enrolled at the end of four years (z = -1.826, p = .034). (Figure 1). The “dropped out” group in Figures 1, 2, and 3 should be interpreted with caution as these groups not only include students who dropped out, but also those who transferred to other institutions. Regardless, the rate of Pell students who left the university by transfer or dropout was greater than non-Pell students, (z = -1.5045, p = .067).

Interestingly, when looking at 5-year graduation rates in STEM and non-STEM, the gaps between Pell and non-Pell students are nearly eliminated (Figure 2). Additionally, both groups’ enrollment rates drop by the end of the fifth year, mostly to graduation and dropout (Figure 2). By the end of the fifth year, the rate of Pell students who left the university by transfer or dropout was significantly greater than non-Pell students,
z = -2.171, p = .015 (Figure 2).

The student outcomes at the end of the sixth year were nearly identical to those of the end of the fifth year. Graduation rates in STEM and non-STEM did not differ by Pell status individually. However, when graduation rates in any major were combined, there was a significant difference between Pell and non-Pell students after six academic years (z = 2.248, p = .012) (Figure 3). The difference between Pell and non-Pell students who left the university due to dropout or transfer increased (z = -2.399, p = .008).

The results of the independent t-tests did not show a significant difference between the Pell and

Figure 1. Four Year Academic Outcomes of Matriculated STEM Majors

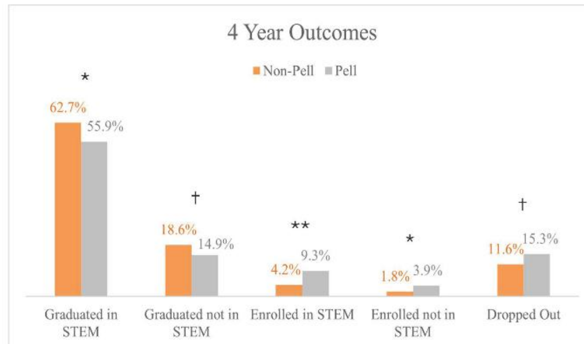

Figure 1. Four Year Academic Outcomes of Matriculated STEM Majors
Note. †p<.1; *p<.05; **p<.01

Figure 2. Five Year Academic Outcomes of Matriculated STEM Majors

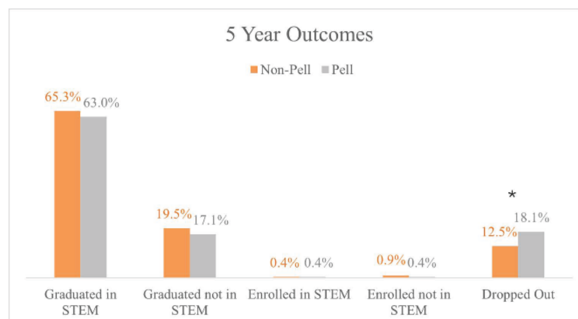

Figure 2. Five Year Academic Outcomes of Matriculated STEM Majors
Note. †p<.1; *p<.05; **p<.01

Figure 3. Six Year Academic Outcomes of Matriculated STEM Majors

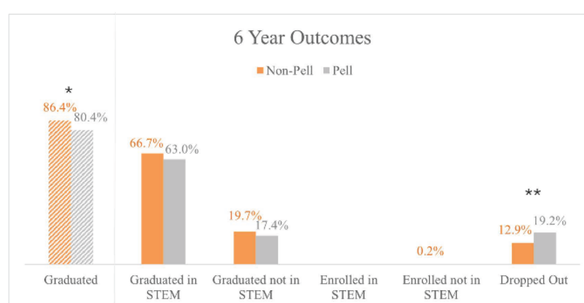

Figure 3. Six Year Academic Outcomes of Matriculated STEM Majors
Note. †p<.1; *p<.05; **p<.01

Figure 4. STEM graduates' cumulative GPA distributions. Green lines indicate median and purple lines indicate mean.

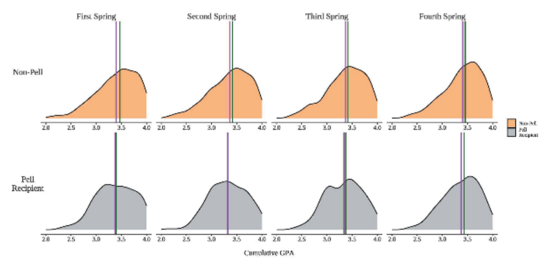

Figure 4. STEM graduates' cumulative GPA distributions. Green lines indicate median and purple lines

non-Pell students after each of the four academic years (Table 4). Specifically, there was no significant effect for group, $t(538) = 0.92$, $p = .3583$, despite non-Pell students ($M = 3.406$, $SD = 0.371$) attaining a slightly higher mean cumulative GPAs than Pell students ($M = 3.375$, $SD = 0.361$) (Table 4).

Discussion and Conclusions

This study found no statistically significant differences in STEM graduation rates or cumulative GPA between lower-income and higher-income students who entered STEM majors in 2014, 2015, or 2016 at this institution. However, when overall graduation rates were examined, including both STEM and non-STEM degrees, lower-income students graduated at significantly lower rates than their higher-income peers, which aligned with our hypothesis. These findings suggest that income-related disparities in STEM degree attainment and academic performance may not be apparent within this sample, yet broader patterns of attrition and degree completion still disproportionately affect lower-income students. This highlights the importance of national reporting on STEM outcomes that are disaggregated by income level.

Additionally, the data reveal that low-income students switched to non-STEM majors at rates statistically similar to those of their higher-income peers. However, low-income students were significantly more likely to leave the institution, either by transferring or dropping out, a trend consistent with previous research (Chen & Soldner, 2013; Estrada et al., 2016). Although both outcomes reduce the likelihood of timely STEM degree completion, they likely arise from different causes. Financial strain, lack of institutional support, and a sense of not belonging may contribute to dropout (Goldrick-Rab, 2010; Ishitani & Kamer, 2024) while transfer decisions may reflect a strategic pursuit of more affordable or better-fitting academic environments (Gallander Wintre & Morgan, 2009; Ott & Zimmerman, 2025) Without distinguishing between these reasons in the dataset, conclusions about student attrition must be interpreted

Table 4. Independent T-Tests of cumulative GPA between Pell & non-Pell students after each academic year.

Pell Status	Term	n	Mean GPA	Median GPA	SD GPA	t	Df	SE	p-value
Non-Pell	**First Spring**	**363**	**3.394**	**3.474**	**0.427**	**0.4961**	**538**	**0.038**	**.620**
Pell	**First Spring**	**177**	**3.375**	**3.398**	**0.398**				
Non-Pell	**Second Spring**	**363**	**3.357**	**3.417**	**0.405**	**0.8578**	**538**	**0.036**	**.391**
Pell	**Second Spring**	**177**	**3.326**	**3.321**	**0.371**				
Non-Pell	**Third Spring**	**363**	**3.370**	**3.419**	**0.386**	**0.8931**	**538**	**0.035**	**.372**
Pell	**Third Spring**	**177**	**3.339**	**3.373**	**0.363**				
Non-Pell	**Fourth Spring**	**363**	**3.406**	**3.456**	**0.371**	**0.9195**	**538**	**0.034**	**.358**
Pell	**Fourth Spring**	**177**	**3.375**	**3.429**	**0.361**				

cautiously, as they obscure important variation in student intent and context.

Most notably, a greater percentage of low-income students took more than four years to graduate compared to higher-income students in both STEM and non-STEM. This finding is particularly consequential, as it suggests that earning a STEM degree requires more time—and therefore more financial investment—for students who can least afford it. Research indicates that extended time to graduation often leads to increased debt, heightened financial stress, and significant loss of income (Aina & Casalone, 2011; Letkiewicz et al., 2014). Given these challenges, STEM Intervention Programs (SIPs) should prioritize efforts to decrease time to graduation for low-income students.

Our SUSTAIN program has demonstrated a positive impact on students from lower socioeconomic backgrounds in multiple ways (Ceyhan et al., 2019; Ceyhan & Tillotson, 2020a; Ceyhan & Tillotson, 2020b). Participants reported that program interventions helped them remain in STEM fields, with faculty mentoring, research experiences, and community-building activities being the most beneficial (Ceyhan et al., 2019). Students who engaged in three or more semesters of research described receiving intellectual, professional, and emotional support from their research mentors (Ceyhan & Tillotson, 2020a). These findings suggest that these combined experiences enhanced their sense of belonging in STEM and contributed to their academic success.

Next steps include further exploration of SUSTAIN's impact on time to graduation, as well as comparative studies between students who participated in the SIP and those who did not. Furthermore, it is recommended that all STEM Intervention Programs incorporate time to graduation as a key measure of program effectiveness.

Acknowledgements

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TESTIMONIALS

Jason doesn't just care about advocating for his students and postdocs—he actively supports their goals with thoughtfulness, energy, and action. Anyone who has worked under his mentorship knows the kind of meeting where he offers three different ideas, suggests two people to contact, shares a hilarious story, and then looks at you and says, "Okay, so now—what do you want? What do you need?" Jason will give you lots of options and lots of resources, but it will always support your specific goals and needs
He knew that my primary goal was to teach, so he arranged for me to lead courses over two semesters at Syracuse University. During the COVID-19 pandemic, when everyone in academia had to rapidly adapt to online teaching, Jason was a steady source of support. He helped me navigate that transition and co-developed a research project assessing students' perceptions of their learning during the pandemic. This collaboration led to one of the earliest published studies shedding light on college student learning during that time.

Beyond his professional support, Jason made me feel genuinely welcomed and cared for. He offered a listening ear and sound advice in moments of uncertainty, but more than that, he and his family opened their home and hearts to me and my husband. We went trick-or-treating with them on Halloween, shared meals together, and I had the joy of spending time with his bright, kind, and hilarious daughter.

What stays with me most is the way Jason balances his professional excellence with a deep, evident commitment to his family. His career reflects his drive, intelligence, and dedication—but his family reflects the generosity and integrity of his heart.

I am deeply grateful to have worked with Jason during my time at Syracuse University, and I look forward to watching the seeds he has planted in so many of us continue to grow and flourish.

Eve Humphrey
Associate Professor
Lincoln University

I would not be where I am today without Jason. Jason took a chance on me as a graduate student at a time when I was ready to give up. He nurtured my curiosity about teaching and taught me to treat pedagogy as any other evidence-based discipline. He helped me develop substantially as both a teacher and a researcher – always with a positive attitude and growth mindset. He supported me in my applications for postdocs and faculty positions and helped me chart a path toward a teaching-focused position where I would be most happy and fulfilled. I owe everything to Jason and am eternally grateful for his guidance and support.

Jeremy D. Sloane, Ph.D.
Assistant Teaching Professor
Biology Department
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815 North Broadway
Saratoga Springs, NY 12866

I met Jason at a pivotal time in my life, which I think is true for nearly all here who have memories to share of him. Jason was always a kind, concerned, and encouraging advisor for me. He shared freely of himself not only as a guide through the oft-troubling world of academia, but also as someone eager to share a recommendation for a band, movie, restaurant, or so many other things. Jason has worked hard to surround himself with those who are unafraid to challenge him academically and is always receptive to feedback, while also working to always improve his own practice. Now that I am beginning to build my own lab, I often find myself thinking of the ways in which Jason subtly offered his support and seek to emulate them myself. One of the things Jason always said to me was that he sought to help his mentees succeed in whatever their goals were, and I saw that play out clearly as a student of his. Unlike some mentors who expect all their students to desire to replace them as a tenure-track professor, Jason instead sought to learn what each of his mentees desired as a career and did his best to provide the opportunities to train for success in those positions. As someone who did desire a tenure-track position, Jason pushed me to seek out and take advantage of opportunities that were uniquely well positioned for that, while reserving other opportunities for those who could be better served by them. That flexibility defines Jason's mentoring style, and it was really impactful to my success, as it likely was for many others. I am happy to participate in this opportunity to reflect on Jason's career and am eager to read the things about Jason that others love as well.

Dr. **Ryan D.P. Dunk**
Assistant Professor, Howard University

When making decisions about graduate school, arguably more important than the research, the department, or the institution, is your mentor. As a master's student, Ph.D. student, and post-doc, I have been incredibly fortunate to have wonderful mentors that have helped shape the course of my career and have taught me valuable lessons. Jason Wiles is one of those mentors – first as the instructor for the large Intro Bio course that I was a TA for while pursuing my masters, and then as my Ph.D. advisor. Jason has many qualities that make him an outstanding mentor – he tailors his mentoring style to the needs of his students, he creates an inclusive and supportive lab culture, and he prioritizes his students' success. But above all else, Jason is an advocate for his students. He listens to your goals and does everything he can to help you achieve them. During the over ten years I have known Jason, my professional goals have continually shifted and he was continually supportive – I did not want to pursue a Ph.D. and then did want to pursue a Ph.D., I did not want to pursue a postdoc and then did want to pursue a postdoc, I wanted to pursue a career in undergraduate teaching and then decided I wanted to pursue a career in ed tech, and then I wanted to leave ed tech and work in science publishing. No matter how many times I changed my mind, Jason has ensured I had access to opportunities and experiences that built my skillset towards reaching my goals and setting me up for success. I am acutely aware that I was afforded opportunities throughout my time as a Ph.D. student that were a direct result of Jason advocating for me and that those opportunities were crucial to my professional development and success.

Additionally, I would be remiss to not also mention Jason as an undergraduate educator. Having taught alongside him in his Intro Biology course sequence at Syracuse University, I have had the privilege to learn from him how to create an inclusive and equitable classroom, how to handle difficult situations, how to create an engaging and effective learning environment, and how to make students feel valued and heard – even when they are one of 600 students in the course that semester.

I am fortunate to have had Jason as my Ph.D. advisor and mentor. His trust, support, and encouragement have been a vital part of my development as a researcher and educator. Beyond that, I am also just fortunate to know Jason as a person. He is kind, driven, positive, and has a great sense of humor. He is a genuine person who I am grateful to have in my corner.

Kelly Schmid

I started my graduate career at the height of the COVID-19 pandemic, which as you may imagine was not the most opportune time. I had visited Syracuse right before the first cases were making news headlines and like many, I was completely unaware as to what that meant for the future. During that visit, one of the first questions Jason asked me was "what do you want to do after you are done here?", I not so promptly replied with "I am not sure yet, but I hope to find out during my time here". He said one thing that has stuck with me and has held true, "I will make sure that you get where you want to be". As a mentor, Jason is invested in the goals and successes of his graduate students. He strived to make sure that I was aware of opportunities that could further my training as a biology education researcher. There were countless experiences that I would have never considered that he saw my capabilities in and recommended I try that have been instrumental in my graduate training. He is more than deserving of this honor and I thank him for all that he has done and continues to do for not only me but past and present members of the lab.

Takunda Maisva

This story will probably be the shortest and least floral of them all, but that comes from my own communication style and not from any shortage of positive sentiment. For context, I'm the kind of guy who avoided wedding vows by getting married in a kitchen right before my wife's dentist appointment – Jason's kitchen, as a matter of fact, because he officiated, and his wife Sarah was our witness. Working with Jason these past couple of years has been delightful, and I shall show my appreciation as I normally do: with a homemade pirate flag as a parting gift.

Taya Misheva

When I first met Jason Wiles, he had a reputation for being the committee member who gave thorough feedback, asked the tough questions, and actually read your drafts line by line. By my third year, he became my co-advisor, which meant I got that level of engagement a lot more often.

Jason has a particular talent for knowing when his students need a push. If I was dragging my feet on submitting a manuscript, hesitating to apply for a conference, or losing steam on a project, Jason made sure I did not stay stuck for long. Whether it came as a word of encouragement, a pointed suggestion, or a direct "you should really do this," he knew how to keep me moving forward, even when I was not especially motivated.

What stands out most is that his pushing always came from a place of genuine care. One of the first things he asked me was, "Where do you want to end up after all of this?" That was not just a casual question. Throughout our time working together, he kept my goals at the center of his mentorship, even when I lost sight of them. Jason never treated his students like projects to be managed. His approach was always people first, work second, though he certainly made sure the work got done.

Jason sets high expectations because he believes in his students and wants them to succeed. Even when he pushed me to do something I was hesitant about, I knew it was because he wanted the best for me and was invested in my success. I am grateful to have had Jason's mentorship through graduate school, especially on the days I did not want to be pushed. I am even more grateful to know he will continue to be a mentor and colleague in the years ahead.

Amanda Surman

Bioscene: *Journal of College Biology Teaching*
Submission Guidelines

I. Submissions to *Bioscene*

Bioscene: Journal of College Biology Teaching is a refereed publication of the Association of College and University Biology Educators (ACUBE). Bioscene is published online only in May and in print in December. Submissions should reflect the interests of the membership of ACUBE. Appropriate submissions include:

- Articles: Course and curriculum development, innovative and workable teaching strategies that include **some type of assessment** of the impact of those strategies on student learning.
- Innovations: Laboratory and field studies that work, innovative and money-saving techniques for the lab or classroom. These do not ordinarily include assessment of the techniques' effectiveness on student learning.
- Perspectives: Reflections on general topics that include philosophical discussion of biology teaching and other topical aspects of pedagogy as it relates to biology.
- Reviews: Web site, software, and book reviews
- Information: Technological advice, professional school advice, and funding sources
- Letters to the Editor: Letters should deal with pedagogical issues facing college and university biology educators

II. Preparation of Articles, Innovations and Perspectives

Submissions can vary in length, but articles should be between 1500 and 5000 words in length. This includes references and tables but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract but not figure or table legends. Concision, clarity, and originality are desirable. Topics designated as acceptable as articles are described above. The formats for all submissions are as follows:

A. Abstract: The first page of the manuscript should contain the title of the manuscript, the names of the authors and institutional addresses, a brief abstract (200 words or less) or important points in the manuscript, and keywords in that order.

B. Manuscript Text: The introduction to the manuscript begins on the second page. It should supply sufficient background for readers to appreciate the work without referring to previously published references dealing with the subject. Citations should be reports of credible scientific or pedagogical research.

The body follows the introduction. Articles describing some type of research should be broken into sections with appropriate subheadings including Materials and Methods, Results, and Discussion. Some flexibility is permitted here depending upon the type of article being submitted. Articles describing a laboratory or class exercise that works should be broken into sections following the introduction as procedure, assessment, and discussion.

Acknowledgment of any financial support or personal contributions should be made at the end of the body in an Acknowledgement section, with financial acknowledgements preceding personal acknowledgements. If the study required institutional approval such as an Institutional Review Board (IRB), the approval or review number should be included in this section. For example, this study was approved under the IRB number 999999. The editor will delete disclaimers and endorsements (government, corporate, etc.)

A variety of writing styles can be used depending upon the type of article. Active voice is encouraged whenever possible. Past tense is recommended for descriptions of events that occurred in the past such as methods, observations, and data collection. Present tense can be used for your conclusions and accepted facts. Because *Bioscene* has readers from a variety of biological specialties, authors should avoid extremely technical language and define all specialized terms. Other than heading titles, the first word in a sentence or a proper noun, authors should not use capitalization, underlining, italics, or boldface within the text. **Authors should not add extra spaces or indentations, nor should they use any hidden from view editing tools.** All weights and measures must be given in the SI (metric) system.

In- text citations should be done in the following manner:

Single Author:

"… when fruit flies were reared on media of sugar, tomatoes, and grapes" (Jaenike, 1986).

Two Authors:

"…assay was performed as described previously (Roffner & Danzig, 2004).

Multiple Authors:

"…similar results have been reported previously (Baehr et al., 1999).

C. References: References cited within the text should appear alphabetically by the author's last name at the end of the manuscript text under the heading references. All references must be cited in the text and come from published materials in the literature or the Internet. Authors should use the current APA style when formatting the reference list.

D. Example citations are below.

(1) Articles-

(a) Single author:

DeBuhr, L. E. (2012). Using Lemna to Study Geometric Population Growth. *The American Biology Teacher*. https://doi.org/10.2307/4449274

(b) Multi-authored three to seven authors:

Green, H., Goldberg, B., Schwartz, M., & Brown, D. D. (1968). The synthesis of collagen during the development of Xenopus laevis. *Developmental Biology*, *18*(4), 391–400. https://doi.org/10.1016/0012-1606(68)90048-1

(c) Mutli-authored more than seven authors

List the first six authors than an ellipsis followed by the last author.

(2) Books-

Bossel, H. (1994). *Modeling and Simulation* (1st ed.). New York, NY: A K Peters/CRC Press. https://doi.org/10.1201/9781315275574

(3) Book chapters-

Glase, J. C., & Zimmerman, M. (1993). Population ecology: Experiments with Protistans. In J. M. Beiswenger (Ed.), *Experiments to Teach Ecology* (pp. 39–82). Washington, DC: Ecological Society of America. Retrieved from https://tiee.esa.org/vol/expv1/protist/protist.pdf

(4) Web sites-

McKelvey, S. (1995). Malthusian growth model. Retrieved November 25, 2005, from https://www.stolaf.edu/people/mckelvey/envision.dir/malthus.html

E. Tables

Tables should be submitted as individual electronic files in Word (2013+) or RTF format. Placement of tables should be indicated within the body of the manuscript. The editor will make every effort to place them in as close a proximity as possible. All tables must be accompanied by a descriptive legend using the following format:

Table 1. A comparison of student pre-test and post-test scores in a non-majors' biology class.

F. Figures

Figures should be submitted as **high resolution** (≥ 300dpi) individual electronic files, either TIFF or JPEG. Placement of figures should be indicated within the body of the manuscript. The editor will make every effort to place them in as close a proximity as possible. Figures only include graphs and/or images. Figures consisting entirely of text will not be accepted and must be submitted as tables instead. No figures put together using a cut and paste method will be accepted. All figures should be accompanied by a descriptive legend using the following format:

Fig. 1. Polytene chromosomes of *Drosophila melanogaster*.

III. Letters to the Editor

Letters should be brief (400 words or less) and direct. Letters may be edited for length, clarity, and style. Authors must include institution address, contact phone number, and a signature.

IV. Other Submissions

Reviews and informational submissions may be edited for clarity, length, general interest, and timeliness. Guidelines for citations and references are the same as described above for articles.

V. Manuscript Submissions

All manuscripts are to be sent to the editor electronically and must comply with the same guidelines for text, figure and table preparation as described above. *Authors must clearly designate which type of article they are submitting (see Section I) for their manuscript to be considered for publication.* Emails should include information such as the title of the article, the number of words in the manuscript, the corresponding author's name, and all co-authors. Each author's name should be accompanied by complete postal and email addresses, as well as telephone and FAX numbers. Email will be the primary method of communication with the editors of *Bioscene*.

Communicating authors will receive confirmation of the submission. Manuscripts should be submitted as a Microsoft Word file to facilitate distribution of the manuscript to reviewers and for revisions. A single-email is required to submit electronically, as the review process is not necessarily blind unless requested by an author. If the article has a number of high resolution graphics, separate emails to the editor may be required. The editors recommend that authors complete and remit the Bioscene Author Checklist with their submission in order to expedite the review process.

VI. Editorial Review and Acceptance

For manuscripts to be sent out for review, at least one author must be a member of ACUBE. Otherwise, by submitting the manuscript without membership, the corresponding author agrees to page charges, which will be the membership fee at the time of submission. Once the authors' membership status has been cleared, the manuscripts will be sent to anonymous reviewers whose name(s) and affiliation will be withheld from the authors. The article will be examined using the Bioscene publishing guidelines stated above. If the manuscript is not in compliance or the authors have not agreed to the page cost provisions stated above, manuscripts will be returned to authors until the page charges have been met. Reviewers will examine the submission for:

- **Suitability:** The manuscript relates to teaching biology at the college and university level.
- **Coherence:** The manuscript is well-written with a minimum of typographical errors, spelling and grammatical errors, with the information presented in an organized and thoughtful manner.
- **Novelty:** The manuscript presents new information of interest for college and university biology educators or examines well-known aspects of biology and biology education, such as model organisms or experimental protocols, in a new way.

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewer(s). The author must address all of the reviewers' comments and suggestions using the original document and **track changes** for any consideration of a resubmission and final acceptance. Revisions and resubmission should be made within six weeks. Manuscripts resubmitted beyond the six-week window may be treated as a new submission. Should manuscripts requiring revision be resubmitted without corrections, the editor/associate editors will return the article until the requested revisions have been made. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. Time from acceptance to publication may take between twelve and eighteen months. The time is determined by the total number of manuscripts submitted.

VII. Revision Checklist

Manuscripts will be returned to authors for failure to follow through on the following:

A. Send a copy of the revised article **using track changes** for text changes back to the associate editor, along with an email stating how reviewers' concerns were addressed.
B. Make sure that references are formatted appropriately in APA style format.
C. Make sure that recommended changes have been made or a clear explanation as to why they were not.
D. Figures and legends sent separately, but placement in manuscript should be clearly delimited.

VIII. Editorial Policy and Copyright

It is the policy of *Bioscene* that authors retain copyright of their published material.

ACUBE
Association of College & University Biology Educators

69th Annual Meeting October 17th- 18th, 2025

Hosted by

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Kingwood, TX

The conference will take place in:
Lone Star College – Kingwood Student Conference Center
20000 Kingwood Drive, Kingwood, TX 77339
https://www.lonestar.edu/kingwood.htm

Editor's note: Some meeting specific local information has been deleted from the original program.

Thank You

Lone Star College – Kingwood

Thank You to 3D Molecular Designs

We extend our sincere gratitude to 3D Molecular Designs for their generous contribution of welcome packets featuring the 3D-printed, AR-enhanced Coronavirus Model. This innovative educational
resource enriches our participants' learning experience by transforming complex scientific concepts into accessible and engaging tools. We deeply appreciate your support and commitment to advancing science education. https://3dmoleculardesigns.com/

Native Americans Attribution

For millennia this area was used and stewarded by the Akokisa who were recorded in historic documents as Orcoquiza/Arkokisa and variant spellings. The Akokisa maintained seasonal villages and traveled the waterways of Galveston Bay, the Trinity River and nearby creeks, including Spring Creek and the present Humble/Kingwood area, for fishing, hunting, and shelter; European contact, disease, and settlement led to the dramatic disruption and dispersal of their communities by the early 1800s. We honor their lives, histories, and enduring legacy on these lands. The Akokisa were an Atakapan-associated coastal people historically documented around Galveston Bay and along the lower Trinity and Sabine rivers. Historic sources describe multiple village groups in the greater Houston area in the 1700s, use of dugout canoes on creeks and bayous, and contact with French and Spanish traders and missionaries in the 18th century. By the 19th century many Akokisa communities had been reduced or absorbed as a result of disease, missionization, and settler expansion. Local historical markers and archaeological work identify Akokisa presence in Harris County near waterways that flow through today's Humble/Kingwood area.

SCHEDULE AT A GLANCE

Friday October 17 2025			
Time	**Event**		
11:00 am – 12:30 pm	Registration – SCC Lobby		
12:30 pm - 1:20 pm	Welcome Session – SCC 104-106		
1:30 pm – 4:45 pm	Strand 1 Sessions - SIB	Strand 2 Sessions - SIB	
4:00 pm – 4:45 pm	Trail Walk Meet - SIB hallway	Learning Garden Tour -SIB hallway	Mindfulness tables SCC 104-106
5:00 pm - 5:50 pm	Poster Session – SCC 104 - 106		
6:00 pm -6:50 pm	Dinner – SCC 108-109 Student Jazz Ensemble		
7:00 pm - 8:00 pm	Awards and Announcements - SCC 108 - 109		
8:30 pm -?	Moth Night SCC		
Saturday October 18 2025			
Time	**Event**		
8:00 am - 8:50 am	Student Mixer Breakfast - SCC 108-109		
9:00 am - 9:50 am	Opening Remarks 104-106		
10:00 am -11:00 am	Keynote Speaker - SCC 104-106		
11:10 am-11:50 am	Strand 3 Sessions - SIB	Strand 4 Sessions - SIB	
12:00 pm – 12:50 pm	Lunch - SCC 108-109		
1:00 pm – 4.25 pm	Strand 3 Sessions - SIB	Strand 4 Sessions - SIB	
4:40 pm – 5:00 pm	Conference Conclusion – SCC 104 - 106		

Our Mission

Members of ACUBE share ideas and address the unique challenges of balancing teaching, research, advising, administration, and service. We are a supporting and mentoring community that provides professional development opportunities to:

- Develop and recognize excellence in teaching
- Incubate new and innovative teaching ideas
- Involve student research in the biology curriculum
- Advise and mentor students in and out of the classroom
- Enhance scholarship through our national, peer-reviewed journal, *Bioscene.*

Governance

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Local Arrangements Chair and Program Chair Brian R. Shmaefsky, Lone Star College - Kingwood

Keynote Speaker Dr. Elizabeth A. Norell

The University of Mississippi Associate Director of Instructional Support

Biography

Dr. Elizabeth A. Norell is an educator, author, and advocate for inclusive and authentic teaching practices in higher education. She currently serves as the Associate Director of Instructional Support at the University of Mississippi's Center for Excellence in Teaching and Learning (CETL). In this position, she collaborates with faculty to design, execute, and publish Scholarship of Teaching and Learning (SoTL) projects, supports assessment activities, and serves as a liaison for social sciences and applied sciences departments.

Dr. Norell's academic journey includes a Ph.D. in political science from the University of Texas at Dallas, as well as master's degrees in journalism from the University of Arkansas and library science from Texas Woman's University. Over the past two decades, she has taught a diverse array of subjects, including composition, journalism, new media, political science, and statistics, at various institutions, including a tenure-track position at Chattanooga State Community College.

Address:

Authenticity and Transformational Teaching

In December 2024, Dr. Norell published her first book, "The Present Professor: Authenticity and Transformational Teaching", through the University of Oklahoma Press. The book explores how educators can foster meaningful student relationships by embracing authenticity and presence in the classroom, offering strategies to improve mental clarity and teaching effectiveness. Dr. Norell will be discussing how to practice the philosophy of her book in this session.

Dinner Music Entertainment in the SCC

Recital Hall – Music Building

The music department at Lone Star College - kingwood offers a dynamic and supportive environment for students pursuing their passion for music. With dedicated faculty, state-of-the-art facilities, and a variety of performance opportunities, the department provides a strong foundation in music theory, performance, and education. Students can develop their skills through ensembles, private instruction, and academic coursework, preparing them for transfer to four-year programs or careers in the music industry.

The music department at Lone Star College – Kingwood has earned recognition for its outstanding student performances, faculty expertise, and strong community engagement. Students and ensembles from the program have received top ratings at regional and state competitions, and many graduates successfully transfer to prestigious university music programs. The department regularly hosts concerts, festivals, and collaborative events that showcase student talent and enrich the local arts community. Faculty members are accomplished performers and educators who bring professional experience to the classroom, helping students achieve high levels of artistic and academic excellence.

The music department at Lone Star College–Kingwood hosts a variety of concerts each year that highlight the talents of students, faculty, and guest artists. Examples include:

- Student Recitals – Solo and small ensemble performances that showcase developing musicians.
- Choral Concerts – Featuring campus choirs performing classical, contemporary, and multicultural works.
- Instrumental Ensemble Performances – Concert band and chamber groups presenting a range of styles from traditional to modern.
- Jazz and Popular Music Nights – High-energy events spotlighting jazz combos and modern music ensembles.
- Faculty and Guest Artist Concerts – Professional performances that provide students and the community with rich cultural experiences.

These concerts are open to the public and help build a strong connection between the college and the surrounding community.

Field Experiences

Moth Night Program

Stuart Marcus – Texas Master Naturalist

The Houston area is home to a remarkable diversity of moth species, from small, delicate leaf miners to large silk moths. These nocturnal pollinators play an essential role in supporting native plants, feeding bats and birds, and contributing to the overall health of our environment.

As we explore the night, light stations and bait traps will be used to attract and observe different species up close. You will discover the subtle beauty, surprising variety, and ecological importance of these nighttime fliers and learn how moths can reveal a lot about the health of local habitats. Examples of moths commonly found in the Houston area:

Large Moths (at least 2.5" wingspan)

Name	Description	Larval Food Source
Luna	Pale green with long tails	sweet gum
Polyphemus	Golden-yellow with large eyespots	oaks
Cecropia	Brown with red patches and white bands	maples, plums
Io	Yellow with large eyespots	privet

Small and Medium Moths

Name	Description	Larval Food Source
Leopard	White with black spots, the caterpillar is the well-known woolly bear	plaintain
Hummingbird	Resembles a small hummingbird and feeds on flowers during the day	honeysuckle
Sphinx	Large family with cryptic coloration, caterpillars include green hornworms	wide variety including pentas and tomatoes

Stuart Marcus retired in 2019 from his position with the U. S. Fish and Wildlife Service as manager of the Trinity River National Wildlife Refuge in Eastern Texas. He worked for the FWS for more than 40 years, and spent another year with the U. S. Forest Service in North Carolina. Marcus is a Florida native and a 1977 graduate of the University of Florida. After college, he briefly worked with his dad before entering the field of wildlife refuge management. He started his career in 1978, first working for the Forest Service in North Carolina and then working for four different refuges in Florida. In 1994, he landed the position of refuge manager for the newly established Trinity River National Wildlife Refuge. He is now an active member of Texas Master Naturalists accumulating nearly 5000 volunteer hours, primarily on moth photography. (Photograph courtesy of Texas Highways Magazine)

Time	**Friday October 17 2025**		
11:00 am – 12:30 pm	Registration – **SCC Lobby**		
12:30 pm - 1:20 pm	Welcome Session – **SCC 104-106**		
	Strand 1		**Strand 2**
1:30 pm – 1: 50 pm	Design Strategies to Increase Meaningful Engagement in Online Discussions – Heather Scherr **SIB 114**	**1:30 pm - 3:00 pm**	Survival in a Changing World: Visualizing Evolution with HHMI BioInteractive and Anole Lizards - Jonelle Orridge & Nilo Marin **SIB 118**
2:00 pm – 2:40 pm	Discovering BacTalk™ — Bringing Bacterial Communication to Life in the Classroom – Leigh Brown **SIB 122**		
2:45 pm – 3:25 pm	Building Ethical Foundations: A Workshop Model for Teaching RCR in Undergraduate Summer Research Program -Khadijah (Gigi) Makky **SIB 114**	**3:20 pm – 3:50**	From Overwhelmed to Organized: Teaching First-year Biomedical Sciences Majors How to Manage their Time - Laurieann Klockow **SIB 118**
3:30 pm – 3:50 pm	Peer-Led Team Learning: A Broad Participatory Engagement Activity Toward Expanding Participation in STEM for All - Takunda Maisva & Jason R. Wiles **SIB 122**		
	Concurrent		
4:00 pm – 4:45 pm	Trail Walk Meet SIB hallway **SIB 112**	Learning Garden Tour -SIB hallway **SIB 112**	Mindfulness tables -**SCC 104-106**
5:00 pm - 5:50 pm	Poster Session – S**CC 104 - 106**		
6:00 pm - 6:50 pm	Dinner – **SCC 108-109** Student Jazz Ensemble		
7:00 pm - 8:00 pm	Awards and Announcements - **SCC 108-109**		
8:00 pm	Moth Night – Stuart Marcus **SCC lobby**		

Time	Saturday October 18 2025	
8:00 am - 8:50 am	Student Mixer Breakfast - **SCC 108-109**	
9:00 am - 9:50 am	Opening Remarks **SCC 104-106** Break Time	
10:00 am 11:00 am	Keynote Speaker - **SCC 104-106**	
	Strand 3	**Strand 4**
11:10 am- 11:50 am	Student Panel Problem- Based Learning Perceptions **SIB 118**	Implementing Undergraduate Research Opportunities through the HHMI SEA-PHAGES Program: Cultivating Scientific Thinking and Faculty Development - Kissaou Tchedre **SIB 122**
12:00 pm – 12:50 pm	Lunch - **SCC 108-109**	
	Strand 3	**Strand 4**
1:00 pm – 2:30 pm	3D Biology Lessons for a Sustainable Future - Kim Grider **SIB 118**	Equations with Life: Mathematical Modeling for Biology Faculty - Kristine Squillace Stenlu, Anita Schuchardt **SIB 122**
2-35 pm – 2:55 pm	Breaking Barriers, Not Just Ice: Designing Community-Building Activities for Online Biology Students – Nourin Amin **SIB 114**	Caution ahead: finding ways to prepare students for challenging coursework in biology - Ashley Driver **SIB 112**
3:15 pm – 3:55 pm	Enhancing Student Engagement in the Biomedical Sciences through Digital Problem-Based Learning - Hosam Abdelhady **SIB118**	Houston Zoo Booth - **SCC** Mindfulness tables – **SCC 104 - 106**
4:05 pm – 4:25 pm	Watching the Summer Tick Away: How the Prevalence of B. Burgdorferi Helped Salvage Student Research Experience - Andrew Karls **SIB 114**	Sustainability as a Living Laboratory: Faculty–Student Partnerships that Scale Learning Beyond the Classroom – Sarah Morgan **SIB-122**
4:40 pm – 5:00 pm	Conference Conclusion - **SCC**	

ABSTRACTS BY CATEGORY

90-minute Workshop Presentations and Special Sessions

3D Biology Lessons for a Sustainable Future
Kim Grider, Hargrave High School; Population Education

Biology and AP Biology courses include units on Ecology – taking a big picture approach to interactions within ecosystems. Environmental Science courses go in more depth on human ecology topics. Our species has an outsized influence on environmental changes. This includes using natural resources which can alter ecosystems such as forests and marine areas, introducing invasive species and pollution, and bringing about changes in climate. The global population has doubled in the past 50 years to 8.2 billion, contributing to significant changes in terrestrial and marine ecosystems. As our population continues to grow, so does the demand for natural resources, affecting fragile ecosystems and habitats.

In this inquiry-based, hands-on workshop, the presenter will facilitate activities with participants that address population ecology, carrying capacity in nature, the importance of biodiversity, and the impacts of the human footprint on ecosystem health. Activity formats include developing and using 3D models to explain ecological phenomena such as carrying capacity in nature, collecting and analyzing population data for different species, and working through a group challenge on sustainable resource management. The presenter will discuss how to implement these activities as part of broadening students' understanding of interdependent relationships in ecosystems.

Participants will come away with strategies for strengthening student skills in analyzing data, identifying patterns, and problem solving around real-world issues. They will also help students use mathematical representations to support explanations of carrying capacity in ecosystems, threats to biodiversity, and paths to sustainability. The presented activities are designed to encompass different learning styles for an inclusive classroom that seeks to engage all students. Participants will receive lesson plans (including assessment suggestions) and background materials, as well as links to digital resources.

Survival in a Changing World: Visualizing Evolution with HHMI BioInteractive and Anole Lizards
Jonelle Orridge, Nilo Marin, Broward College

What can anole lizards teach students about surviving and thriving in rapidly changing environments? Using a suite of HHMI BioInteractive resources, facilitators will demonstrate how real data, and a model organism can support students in connecting important concepts such as natural selection, evolution, and the process of science. In the workshop, participants will use interactive modules, activities, and a new short film to analyze data, investigate the impact of current human environmental pressures on anole evolution, and discuss the implementation of these resources with other participants.
This hands-on activity will require participants to use their electronic devices, i.e., tablet or laptop.

Equations with Life: Mathematical Modeling for Biology Faculty
Kristine Squillace Stenlund, Anita Schuchardt, University of Minnesota

This workshop is designed to support biology faculty in exploring the use of mathematical modeling as a strategy for fostering deeper student understanding of the connections between mathematics and biological phenomena. While mathematics is often employed in science classrooms primarily for computation, data analysis, or representation, students frequently struggle to interpret how mathematical representations connect to underlying mechanisms and patterns in biology. This limitation can reduce their problem-solving capacity to memorize approaches rather than supporting transfer to novel contexts. Mathematical modeling has been identified as a promising instructional practice that can strengthen conceptual understanding and quantitative reasoning while promoting the integration of mathematics and sciences. In particular, introductory level students are poised to benefit from such an approach early in their education transferring this fluency as they continue to learn.

During the workshop participants will engage in both experiential learning and pedagogical reflection. Participants will first engage in a modeling task from the perspective of students, collaboratively developing a mathematical equation to represent a selected biological phenomenon. Whole-group discussion will highlight similarities and differences across models, allowing participants to examine the strengths and limitations of different approaches and how these representations can reveal or obscure biological insights. Next participants will discuss the pedagogical implications of mathematical modeling. Participants will identify affordances and constraints associated with the practice, as well as instructional strategies that can encourage students to connect quantitative models with scientific explanations. Research-based findings on the role of modeling in supporting learning will be presented for further discussion. Finally, participants will discuss possible strategies from the workshop activities to incorporate into their own teaching contexts.

Through this experience, faculty will leave with a deeper understanding of mathematical modeling in biology instruction, concrete examples of classroom application, and strategies to promote student engagement in linking mathematics to biological phenomena.

20-minute Presentations

Building Cultures of Care: Fostering Belonging in the Science Laboratory

Brian Shmaefsky, Lone Star College – Kingwood

Scientific laboratories are not only spaces of discovery and innovation—they are also social environments where culture, relationships, and power dynamics deeply shape the experiences of students, researchers, and staff. This session explores the concept of the laboratory as a "community of care," where inclusive practices, mutual support, and a sense of belonging are integral to scientific success. Drawing on interdisciplinary perspectives and lived experiences, participants will examine how mentorship models, communication norms, leadership styles, and physical spaces impact emotional well-being, equity, and collaboration. Through case studies, facilitated discussions, and practical strategies, this session invites attendees to reimagine lab environments as inclusive ecosystems that value care as a core scientific ethic. Ideal for faculty, lab managers, graduate students, and institutional leaders, the session aims to inspire actionable change toward more compassionate and equitable scientific communities.

Peer-Led Team Learning: A Broad Participatory Engagement Activity Toward Expanding Participation in STEM for All

Takunda Maisva, Jeremy D. Sloane, Ryan D. P. Dunk, Julia J. Snyder, Christina I. Winterton, Kelly M. Schmid, Mariah C. Maxwell, & Jason R. Wiles, Syracuse University

Efforts toward broadening participation in STEM continue to be of great importance if the United States is to meet its need for an innovative STEM workforce. Peer-Led Team Learning (PLTL) is a collaborative, active learning pedagogical model that has been shown to support students through increased achievement and persistence in STEM. In this study, we examined both the short and long-term outcomes of PLTL participation in undergraduates enrolled in Introductory Biology at our institution over a five-year period. We investigated the association between PLTL participation and meeting the threshold for declaring a Biology major (earning a grade of C+ or better), graduation in general, and graduation in a STEM major. Outcomes were disaggregated by URM status, first generation college status, and student-reported sex identity (the only gender-related data collected institutionally). Results indicated that PLTL participation was associated with increased achievement across all groups. Disparities in performance between URM and non-URM students and between first-generation and continuing generation students were statistically significant in the non-PLTL groups of students, but not in the PLTL groups indicating that gaps were statistically closed. Regression models were used to assess PLTL as a predictor of course performance and final GPA. Participation in PLTL was associated with higher rates of STEM degree attainment for female-identifying students, non-URM students, continuing-generation students, and male students. Moreover, we observed higher baseline rates of achievement and graduation for all groups compared to earlier cohorts. These findings suggest that PLTL remains an effective and inclusive active learning strategy that promotes student achievement in STEM, especially for gateway courses.

Breaking Barriers, Not Just Ice: Designing Community-Building Activities for Online Biology Students
Nouran Amin, Ball State University

Traditional icebreakers are a common feature in college classrooms, designed to encourage participation, ease anxiety, and build rapport. However, depending on how they are framed and implemented, they can sometimes lead to discomfort, disengagement, or missed opportunities for genuine connection. This presentation explores how reframing icebreakers as "community-building activities" can create more purposeful and meaningful opportunities for student interaction within the accelerated format of a five-week online biology course for non-majors. Drawing on student reflection data, the session highlights how creative and enjoyable activities are most effective when woven directly into the structure and content of the course. Participants will gain practical strategies for designing community-building activities that promote engagement, support student success, and tie participation back to disciplinary learning goals in online, asynchronous settings.

Design Strategies to Increase Meaningful Engagement in Online Discussions
Heather Scherr, Lone Star College – Kingwood

Asynchronous online discussions are often criticized for merely being a means to meet the teamwork requirement in an online course. These discussions may suffer from several issues: a lack of meaningful student interaction, insufficient accountability and participation, single due dates resulting in limited discussion time, and the use of completely AI-generated responses. To address these challenges, I have developed several discussion design strategies. Using consistent, thoughtfully constructed student groups and multi-part case studies can build community, potentially increasing accountability. Each discussion is broken down into 3 elements—initial posts, collaboration, and final answers—with progressive due dates, forcing sufficient discussion time. Instructions are organized in collapsible sections, allowing both detail and digestibility. Some posts require student videos to promote and demonstrate oral communication, increase accountability, and potentially reduce total reliance on AI. Finally, I employ LMS-automated notifications to prompt straggler participation. While my approaches employ specific tools, they are adaptable to other platforms.

Caution ahead: finding ways to prepare students for challenging coursework in biology
Ashley Driver, University of Scranton

The blank stares. The awkward silence. The panic. The seemingly simple question of "what happened?" and the oft-repeated response of "…I don't know, I really tried." A feeling of helplessness from both sides of the table can be felt as student and instructor meet after the first exam. It's likely that we have all been there, and yet preventing this situation from recurring remains elusive. How can we get through to students earlier? What can be done differently? This session will focus on brainstorming approaches to improve student awareness and reflection early in a biology course. Participants should come prepared to discuss their own strategies and move forward towards potential solutions!

Watching the Summer Tick Away: How the Prevalence of B. Burgdorferi Helped Salvage Student Research Experience
Andrew Karls, Lakeland University

This past summer, I took on a research student for a 10-week HEK 293 cell-culture based project; unfortunately, our incubator failed in week three, requiring us to pivot. Given the cost of repairs and the money already invested, developing and executing a new project in a short timeframe felt daunting, until my dog picked up a deer tick, I. scapularis, on a walk. After a trip to the vet and a test for Lyme disease, I began to consider how the test itself was performed – in most cases, it's simply done via PCR, where a gene specific to B. burgdorferi (the spirochete bacterium transmitted by I. scapularis and the causal agent for Lyme disease) is targeted for amplification. Although I hadn't performed much PCR in my career, I knew we had a thermocycler on hand and the cost of a DNA extraction kit was modest. Soon, the idea of surveying ticks near campus began to emerge. In this presentation, I'll explain how a quick shift led to a low-cost research project that engaged both the student and the community. I'll discuss our results, their implications, and how we expanded upon the original idea. Finally, I'll suggest ways in which what we did can be adapted for other undergraduate research experiences.

Sustainability as a Living Laboratory: Faculty–Student Partnerships that Scale Learning Beyond the Classroom
Sarah Morgan, Lone Star College- CyFair

How can sustainability initiatives on campus transform from classroom projects into lasting student leadership opportunities? This session explores the power of faculty–student partnerships in scaling biology and environmental science learning beyond the classroom. Drawing on experiences at Lone Star College, we highlight one initiative: the annual Sustainability Day Summit. This serves as “living laboratories” where students connect scientific concepts to real-world challenges, develop leadership skills, and engage with community and industry partners.
Student officers from the Environmental & Sustainability Club will share their perspectives on co-leading these projects, reflecting on how faculty mentorship empowered them to apply biology knowledge, organize events, and build professional networks. Participants will leave with practical strategies to create similar bridges between coursework, student clubs, and campus sustainability projects. This session offers models, templates, and guiding questions to help attendees replicate and adapt these partnerships, turning their own campuses into fertile ground for student innovation and civic engagement.

40-minute Presentations

Implementing Undergraduate Research Opportunities through the HHMI SEA-PHAGES Program: Cultivating Scientific Thinking and Faculty Development
Kissaou Tchedre, Austin Community College

Enhancing Student Engagement in the Biomedical Sciences through Digital Problem-Based Learning.
Hosam Abdelhady, Sam Houston State University College of Osteopathic Medicine

This session will present how Problem-Based Learning (PBL) can transform digital biomedical education by fostering self-directed learning, critical thinking, and scientific problem-solving. At Sam Houston State University College of Osteopathic Medicine, we use PBL to immerse students in authentic patient cases rooted in biological and physiological concepts, encouraging them to actively seek, analyze, and apply information. This method bridges foundational biological knowledge with its clinical and societal applications, preparing students for complex, real-world challenges.

Discovering BacTalk™ — Bringing Bacterial Communication to Life in the Classroom
Leigh Brown, Bio-Rad Laboratories, Inc.

How can you get your students to see the invisible conversations happening between microbes? In this interactive 40-minute presentation, we’ll introduce you to Bio-Rad’s BacTalk™ Cell Signaling Kit, a hands-on lab experience that brings the cutting-edge science of quorum sensing into the undergraduate biology classroom.
Quorum sensing is the molecular language bacteria use to coordinate group behaviors, from bioluminescence to virulence. With BacTalk Cell Signaling Kit, students don’t just read about it—they observe it directly by working with classroom safe Vibrio campbellii strains that glow only when their “neighbors” send the right chemical signal. The kit provides a rare opportunity for students to explore gene regulation and intercellular communication in living cells, while reinforcing core concepts in microbiology, molecular biology, and biotechnology.
During this session, you’ll step into the role of your students:

- Learn how the kit’s three bacterial strains reveal the genetic “circuitry” of quorum sensing.
- See how simple classroom experiments make invisible chemical signals visible through bioluminescence.
- Explore how BacTalk can anchor discussions of antibiotic resistance, microbial ecology, and the evolution of cooperation.

We’ll also highlight flexible teaching strategies for different course levels, from general biology to microbiology and molecular genetics. You’ll leave with practical ideas for integrating BacTalk into your lab curriculum, connections to broader learning objectives, and a sense of how this engaging system can spark curiosity and deeper understanding. Come experience BacTalk for yourself—and imagine how it could transform your students’ view of bacteria from simple pathogens to sophisticated communicators.

From Overwhelmed to Organized: Teaching First-year Biomedical Sciences Majors How to Manage Their Time
Laurieann Klockow, Marquette University

The transition from high school to college often leaves first-year students struggling with unstructured time, stress, ineffective study strategies and procrastination, challenges that are amplified in rigorous science majors. To address this, we taught a three-part interactive workshop that provides first-year biomedical sciences majors with a systematic approach to time management, aimed at reducing stress and establishing effective routines to support success in demanding science curricula.

While this workshop was implemented in the context of a semester-long BISC success course, it could be adapted for other contexts. It could be scaled as a one-time session, incorporated into advising or orientation programming, or shared informally through faculty office hours.

The workshop progresses from semester-level planning to weekly routines to daily action steps. Rather than focusing only on tools, students are guided to reframe their time as a student as equivalent to a full-time job, to recognize routines as stress reduction and to translate vague goals such as "study biology" into actions. By the end of the 3-part module, students leave with a sustainable habit of semester-level, weekly and daily planning.

Survey data at the end of the course indicated increases in self-reported confidence using time management strategies such as Master Calendars and digital calendar apps. The proportion of students describing themselves as "fairly" or "very confident" in their academic success also increased.

This presentation will share the workshop's materials and strategies, highlight lessons learned during its implementation, and review student feedback on its overall impact. By sharing these resources, we aim to help students transition from feeling overwhelmed to feeling organized and in control.

Building Ethical Foundations: A Workshop Model for Teaching RCR in Undergraduate Summer Research Program.
Khadijah (Gigi) Makky, Marquette University

Undergraduate research is considered one of the most impactful teaching practices. In addition to preparing students for careers in research, it provides experiential learning that helps them develop critical skills such as analytical thinking and attention to detail. Student involvement in research has been steadily increasing. According to the Council on Undergraduate Research, there are over 600 summer research programs for undergraduates in the United States, particularly in STEM fields. These programs are hosted by a wide range of institutions, including large research universities with federal funding, liberal arts colleges, and specialized institutes supported by various funding sources. Much of this involvement can lead to peer-reviewed publications.

As more undergraduates engage in research, it has become increasingly important to provide training in research ethics. Learning about the Responsible Conduct of Research (RCR) helps students understand how to conduct research honestly, responsibly, and ethically.

In our Biomedical Sciences department at a four-year Jesuit institution, we offer a summer research program that typically includes 25–35 students. These students spend the summer working on projects funded by federal grants (from the National Science Foundation (NSF) and the National Institutes of Health (NIH)) as well as internal grants. This 10-week research experience immerses students in hands-on research, culminating in a poster presentation of their projects at the end of the summer. Students also receive training in lab and chemical safety, animal handling, and attend a workshop on the Responsible Conduct of Research.

We designed the RCR workshop to be engaging and data-driven, helping students recognize its importance. To assess its effectiveness, we surveyed students before and after the workshop to evaluate their understanding of RCR-related issues. In this presentation, we share the original design of the workshop and the survey data, which highlight the value of offering such training at the beginning of a research program.

Poster presentations

Engaging Students in Exploring the Effects of Endocrine Disruptors Through Molecular Storytelling.

Brian R. Shmaefsky, Lone Star College – Kingwood

A water bottle that is BPA free, a shampoo that is parabens free - we see these labels on products we buy and in various multimedia. In collaboration with the Molecular CaseNet FMN, I have developed an engaging environmental toxicology lesson to deepen students' understanding of how this class of synthetic and natural chemicals interfere with and disrupt hormonal functions, hence the name Endocrine Disruptor Chemicals (EDCs). The lesson uses a molecular storytelling approach to illustrate the biological mechanisms and real-world consequences of endocrine disruption in molecular detail. This example focuses on how a specific EDC (called DDT) and how it interferes with the function of the estrogen receptor. Students will learn about the structure and function of estrogen receptors in biology. They will investigate the impact of DDT binding on endocrine function. By combining narrative techniques with scientific inquiry, the lesson engages students in critical thinking about environmental exposures, regulatory challenges, and public health implications.

Using a Herbarium Collection to Augment Research and Teaching

Camellia Moses- Okpodu, University of Wyoming

Leafy Spurge (*Euphorbia esula*), a resilient invasive species in the Rocky Mountain region, serves as the focal point of my research into plant epigenomics. By examining how gene expression in Leafy Spurge is regulated in response to environmental stimuli, this work reveals adaptive strategies that may be shared by other native and invasive species. These insights are critical for understanding plant responses to ecological pressures and for informing biodiversity conservation and invasive species management.

This research also explores the broader ecological interactions of Leafy Spurge, including its relationships with fungi, microbes, and herbivores. Epigenomic modifications can influence these interactions, shaping community dynamics and ecosystem resilience.

Importantly, this work demonstrates how herbarium collections can be leveraged to enhance both research and teaching. By integrating epigenomic data with historical specimens, we can track genetic and phenotypic changes over time, correlate them with environmental conditions, and inform conservation strategies. Herbarium records thus become powerful tools for understanding plant evolution, adaptation, and ecological function—while also serving as engaging, data-rich resources for student learning in genomics, ecology, and conservation biology.

Isolation, Identification, and Characterization of Antibiotic-producing Bacteria from Soil.

Crystal Robert O. Portillo, Brenna G. Ploof, Roxana X. Torres, Isabella E. Sulvaran, Anna K. Webster, Allie E. Seybert, Mohammad A. Alsaedi, Shima Chaudhary, Lone Star College – Kingwood

Soil ecosystems harbor diverse microbial communities, including antibiotic-producing bacteria that play key roles in microbial interactions and contribute to the dissemination of antibiotic resistance genes (ARGs). To address the widespread resistance to known antibiotics, the discovery of novel antibiotic producers is important. In this study, twenty soil samples were collected from various regions of Harris County, Texas, to isolate antibiotic-producing bacteria. The isolates were screened for antimicrobial activity against known ESKAPE-safe relative bacterial isolates. A total of 28 bacterial isolates were initially identified; however, only 12 maintained consistent antibiotic production after storage and were selected for further characterization. These isolates were identified using 16S rRNA gene amplification with universal primers (27F/1492R), followed by sequence analysis. The isolates were classified within the genera Bacillus, Pseudomonas, Priestia, and Rossellomorea, indicating substantial genetic and potential functional diversity.

To evaluate the effectiveness of antibiotic production, a bioassay using Caenorhabditis elegans (C. elegans) was conducted. Three isolates were selected for this assay: AS2 (Bacillus cereus, GenBank: AB996598), MA15 (Bacillus siamensis strain TKM9, GenBank: ON564825.1), and BG4 (Pseudomonas aeruginosa strain DD3, GenBank: PP413726.1). Cell-free extracts (CFCs) were prepared by centrifuging 48-hour cultures grown in Luria-Bertani broth and collecting the supernatants. The motility of juvenile stage four and adult C. elegans was then monitored following exposure to the cell-free extracts to assess potential antimicrobial or toxic effects. CFC test results from isolates AS2 and MA15 significantly inhibited the motility of C. elegans. These results suggest a promising anthelmintic effect of the tested isolates.

A New Plastic Eater: Analysis of C. Freundii For its BioRemedial Effects on Polyurethane
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This study investigates the impact of Citrobacter freundii on polyurethane with the aim to explore its capabilities for bio-remediation. Previous researchers have looked for plastic degrading organisms from sources such as fungi and soil. More recent scholarship has investigated plastic degrading microorganisms within insects, most promising the Klebsiella oxytoca in the yellow mealworm. Using the phylogenetic tree of Klebsiella oxytoca, Citrobacter freundii was selected as the optimal organism due to its close evolutionary relationship and economic viability. This study hypothesized that Citrobacter freundii is able to degrade polyurethane based on the fact that it is in the same genus as other plastic degrading microorganisms. To determine if Citrobacter freundii can break down polyurethane two methods were utilized: UV visible spectroscopy and colony counting. Bacterial cultures and broth grown using polyurethane modified media were utilized. These bacterial cultures in the test tubes grew as evidenced by increased optical density absorption over time. However, no visible colonies were found in the agar but upon further examination via microscopy there were some signs of bacteria present which means this test was inconclusive . The hypothesis of this study is somewhat supported as the data showed that Citrobacter freundii was able to utilize polyurethane as a carbon source as evidenced by the findings of the UV visible spectroscopy test. More time and resources are needed to study Citrobacter freundii but this organism shows great potential to be an alternative to dispose of plastic and is worth investigating further given the preliminary data.

The Mediterranean Diet and Premature Birth: The Interplay Between Proinflammatory Cytokines and 11β-Hydroxysteroid Dehydrogenase 2
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With an aim to determine the mechanism by which the Mediterranean Diet (MD) decreases the risk of premature birth, this study examines the relationship between proinflammatory cytokines, 11β-Hydroxysteroid Dehydrogenase 2 (11β-HSD2), and cortisol. Adherence to the MD decreases both cortisol levels and the risk of premature birth, while high cortisol levels are linked to increased risk of premature birth. Increased levels of proinflammatory cytokines TNF-α, IL-1β, and IL-6 inhibit 11 β-HSD2 activation, increasing fetal cortisol exposure and subsequently raising premature birth risk. The MD may lower increases in proinflammatory cytokines, therefore explaining how MD adherence lowers the risk of premature birth. A literature review was conducted to examine the correlation between the MD and proinflammatory cytokine levels. Flor-Alemany et al. found that TNF-α levels decreased at the 34th gestational week with higher MD adherence, while Ramon Estruch found that IL-6 levels decreased with MD adherence supplemented with mixed nuts and olive oil. Additionally, Koelman et al.'s systematic review of MD adherence revealed that TNF-α, IL-1β, and IL-6 concentrations significantly decreased. Synthesis of these results suggests that the MD's ability to lower proinflammatory cytokines increases 11β-HSD2 activation, thereby reducing fetal cortisol exposure and decreasing the risk of premature birth. Future research should analyze inflammatory cytokine concentrations in preterm births from mothers who did and did not follow the MD to test the validity of this conclusion.

Antioxidant - A Term Too Broad in the Context of Cancer
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With an aim to clarify contradictions regarding the impact of antioxidants in cancer treatment, a systematic literature review was conducted examining how different antioxidants affect temozolomide (TMZ) therapy in glioblastoma.
Antioxidants have been shown to induce resistance to treatment in many instances but enhance sensitivity in others. This research hypothesized that the impact correlates with the primary mechanism in action: scavenging reactive oxygen species (ROS) or modulating pathways. Three antioxidants were reviewed with a single, consistent impact on TMZ–glutathione, curcumin, and resveratrol–to identify their underlying mechanism. N-acetylcysteine (NAC)–an antioxidant that has shown both impacts of either resistance or enhancement–was analyzed as two separate antioxidants, based on impact, to highlight the primary role of mechanism in influencing the outcome of TMZ. As a result, a correlation was identified between ROS-scavengers with inducing resistance and pathway-modulators with enhancing sensitivity, confirming that antioxidants are not inherently contradictory but contextually dependent on mechanism in action. This research may extend to other cancers treated with similar oxidative stress-inducing therapies, suggesting a broader applicability of the mechanistic categorization. However, future research is needed to understand the factors that determine whether an antioxidant will act primarily as an ROS-scavenger or a pathway-modulator in order to effectively control outcomes to TMZ