Bioscene
Journal of College Biology Teaching

Volume 50 | December 2024

Bioscene
Journal of College Biology Teaching

Volume 50 **December 2024**

ISSN 1539-2422

A Peer-Reviewed Journal of the

Association of College and University Biology Educators

Editor-in-Chief:
Robert W. Yost
Indiana University
Indianapolis

An archive of all publications of the Association of College and University Biology Educators (ACUBE) can be found at http://acube.org/bioscene

Bioscene is now published online in December. Manuscripts submitted for consideration by Bioscene should follow the guidelines for submission.

Cover image
Hernandez's helmeted basilisk lizard (*Corytophanes hernandesii*) photographed in a lowland tropical rainforest along the Bladen River in Southern Belize

Photographer
Paul Pickhardt, Professor of Biology, Lakeland University

CONTENTS

EDITORIAL & GOVERNANCE INFORMATION...2

ARTICLES 3

Science on the Go: Evaluating Experiential Learning Assignments Across Science Disciplines...3
Trisha Mahtani, Amy Jenne, Ayuni Ratnayake, Zohreh Shahbazi, Nirusha Thavarajah, and Aarthi Ashok

Mystery Encourages Engagement and Interest in Plants................................16
Aditi Sinha, Ph. D

Student Success in a Mixed-Major Animal Behavior Course..........................22
Sarah Fauque

Leveraging an upper-level microbiology CURE to advance scientific communication skills..32
Ebenezer Korkor and Rebekka Darne

INNOVATIONS...43

A Framework for Scaling-up Community-Engaged Research Experiences in Introductory General Biology Laboratories...43
Eva N. Nyutu, Víctor Carmona-Galindo, and Maris Polanco

A Few Ideas for Biology Labs on a Budget
Robert Wolff...52

2024 ACUBE Annual Meeting

Program...54

Abstracts...62

Attendees..72

SUBMISSION GUIDELINES...77

.

Bioscene: *Journal of College Biology Teaching*
Volume 50 December 2024

A Publication of the Association of College and University Biology Educators

ACUBE Mission Statement

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*.

2026 Meeting
Lone Star College-Kingwood in Kingwood, Texas
Please check ACUBE website for dates and times

Articles

Science on the Go: Evaluating Experiential Learning Assignments Across Science Disciplines

Trisha Mahtani[1], Amy Jenne[2], Ayuni Ratnayake[1], Zohreh Shahbazi[3], Nirusha Thavarajah[4] and Aarthi Ashok*[1]

*corresponding author; [1] Department of Biological Sciences, University of Toronto Scarborough, [2] Department of Chemical & Physical Sciences, University of Toronto Mississauga, [3]Department of Computer and Mathematical Sciences, University of Toronto Scarborough, [4]Department of Chemical & Physical Sciences, University of Toronto Scarborough, Toronto, Canada.

Abstract

Undergraduate STEM students have limited opportunities to apply course-acquired knowledge in the community. Experiential learning opportunities that connect students with community partners offer one impactful way to apply course learning to communities within and beyond the university. While studies have established the value of experiential learning in building skills, few have explicitly invited students to articulate their experience and perceived value of community-based experiential learning. We designed a comparative research study to examine the student experience in community-based experiential learning assignments in three STEM courses at a research-intensive public university in Canada. Students from participating courses were invited to complete an anonymous survey and join focus groups to provide valuable insights on their experiences and skill development through experiential learning assignments. We found that the nature of the assignment and opportunity to clearly connect the experience to course content had an impact on student-reported outcomes. In addition, we found some discipline-specific differences in student reported learning and transferable skill development. Overall, students found their experiences enriching and reported on skill development and the value of community-partnered work. These models could be adapted by other instructors to enhance the learning experiences of students in STEM programs.

Keywords: community-partnered experiential learning, higher education, STEM, transferable skill development, student experience

Introduction

Opportunities for student learning outside of the classroom in which they engage with community-partnered projects, allows them to see the value of their learning in STEM (Astin et al., 2000; Begley, 2013; Kalas & Raisinghani, 2019; Kulesza et al., 2022). Applying course-learning in the broader community context has been shown to promote a better sense of belonging to the scientific community and renewed interest in coursework, which have important benefits for overall learning and student retention in these fields (Brownell & Swaner, 2012; Gallini & Moely, 2003). Previous work has also established the value of experiential learning assignments in developing transferable skills such as critical thinking, communication, and collaboration (Billig & Eyler, 2003; Jackson & Wilton, 2016; Smith, 2014). Participation in experiential learning can help students discover career options and better prepare them to consider future careers in STEM (Gibbs, 2022; Jackson, 2017; Peters et al., 2014). While experiential learning assignments have been established as valuable learning and community engagement tools, there is a limited understanding around the impact these types of assignments have on student learning and skill development across different STEM disciplines. Student perceptions and attitudes within different STEM disciplines can differ in the context of student identity (Wong et al., 2023), self-efficacy (Whitcomb et al., 2020), and sense of belonging (Veldman et al., 2021). Therefore, it is important to understand how experiential learning can impact overall student learning within a variety of STEM courses.

As such, we were inspired to examine experiential learning assignments in three fourth-year STEM courses (in the disciplines of biology, chemistry, and math) at the University of Toronto Scarborough (UTSC). Our collaborative project and comparative study we titled “science on the go”, to illustrate the broader community focus of the learning experiences we designed and investigated. In each of the three participating courses, students worked with a community partner to create a resource or presentation to engage and inform either the partner themselves, members of the public, or fellow peers on a topic of interest. We hypothesized that this experience would 1) engage students, 2) generate an appreciation for their university education by connecting their course learning to the community, and 3) build key transferable skills as part of the process. We also hoped that this assignment would significantly enhance student self-efficacy across STEM disciplines and result in positive impacts on all students' abilities to apply to and interview for future careers in STEM (Freudenberg et al., 2011; Freudenberg & Subramaniam, 2007; Pretti & Fannon, 2018). We used a mixed methods approach: survey instruments and focus groups were both used to observe and evaluate the impact of the experiential learning assignments in each of the participating STEM courses. Here, we describe the details of the science on the go assignments and the findings from our study, which we hope will inspire other instructors to adapt our design to enhance the student learning experience in STEM.

Methods

Participants

The science on the go pilot project involved comparing experiential learning assignments across three fourth year STEM courses in biology (BIOD29: Pathobiology of Human Disease), chemistry (CHMD47: Advanced Bio-Organic Chemistry) and math (MATAD02: Classical Plane Geometries) (Table 1). The project was funded by the Dean's Experiential Learning Fund (UTSC) and the pedagogical research study was approved by the University of Toronto Research Ethics Board (Protocol #: 00038372). The pilot study was initiated in September 2019 in the math course (MATAD02). Due to the COVID-19 pandemic, the pilot was delayed in the biology (BIOD29) and chemistry (CHMD47) courses until January 2022. Hence, math students had in-person interactions with their community partners, while chemistry and biology students interacted virtually (Table 1). Students in biology and math were connected with community partners through the assistance of the Integrated Learning Experience (ILE) team at UTSC. Chemistry students were asked to identify their own community partners from the broader community. MATAD02 community partners included a national institute for the blind, a robotics academy, arts organizations, architecture firms, and engineering firms. BIOD29 community partners included arts organizations, public libraries, a citizen's climate lobby, and a palliative care facility. CHMD47

Table 1. Course Details, Enrollment, and Specifics of the Science on the Go Assignments in Each of the Participating Fourth-Year STEM Courses.

Course	Enrollment	Assignment Outline
BIOD29: Pathobiology of Human Disease (Jan.-Apr. 2022, virtual)	40 (22 survey respondents, 3 focus group participants)	Students worked in groups of 4-5 to deliver one 50-minute workshop for their assigned partner's needs.
CHMD47: Advanced Bio Organic Chemistry (Jan.-Apr. 2022, virtual)	17 (11 survey respondents, 2 focus group participants)	Students interviewed a community partner in their field. They learned about the application of chemistry and discussed strengths and weaknesses of the partner's work with an EDI lens. Students identified content from the course that was directly applicable in addressing the issues learned from the interview.
MATAD02: Classical Plane Geometries (Sep.-Dec. 2019, in person)	50 (22 survey respondents, 0 focus group participants)	Students visited a site partner, presented a 5-minute introduction to their assigned course topic (with no jargon) and posed 3 research questions to conduct interviews and establish how their research topic is applied in the workplace.

community partners included professors at University of Toronto and UTSC, an engineer at Canadian Nuclear Laboratories, a pharmacist in Thailand, an analytical scientist at a pharmaceutical company, and a project manager at Resilience Biotechnologies. The details of each course's experiential learning assignment are provided in Table 1.

Design

Upon completion of the assignment, all students enrolled in the participating courses were invited to complete an optional and anonymous survey (Appendix) to report on their learning and overall experience with the assignment (consent rate = 55% of BIOD29 students, 65% of CHMD47 students and 44% of MATAD02 students). Some survey questions used a Likert scale rating from 1 (strongly disagree) to 5 (strongly agree). Agree and strongly agree responses (4 and 5) were aggregated as the positive responses. Five students from the participating biology and chemistry courses also participated in focus group interviews facilitated by two research assistants in June-July 2022. As over two years had elapsed since the assignment in the math course (MATAD02), these students were not invited to participate in focus group discussions. Questions in the survey instrument and focus groups were designed to address the science on the go project learning outcomes (Table 2).

Analytic strategy

Qualitative analysis of the focus group transcripts and open-ended survey questions was performed using the NVivo platform (NVivo12, Lumivero). Responses were coded into specific categories, aligned with our research questions outlined below.

Results and Discussion

In our comparative research study, we considered the following questions for interpreting and analyzing the survey data and focus group transcripts:

- Did students feel they were able to successfully create content for a broad and diverse audience? (learning outcome 1)
- Did the assignment improve student learning in the course and help students connect their course material to everyday life? (learning outcomes 4 & 6)
- Did the assignment allow students to enhance their understanding of the subject matter? (learning outcome 6)
- Did students enhance their work-ready skills or develop new transferable skills (e.g., communication, teamwork, science communication, creative thinking)? (learning outcomes 2, 3, & 5)
- Did the assignment broaden their world view, prepare them for work experiences, or help identify new career options? (learning outcomes 4 & 7)
- How did the experiences of students differ among the participating STEM courses with regard to this assignment?

Our analysis of the survey responses and interview transcripts from the focus group revealed that most of the student feedback was positive. At least 50% of students in each course reported a positive learning experience and reported that at least four of the seven assignment learning outcomes were met as part of their experience.

Students' perceptions of the assignments

Students in all three courses enjoyed the experiential learning assignments and thought the assignments were appropriately weighted based on the workload (Figure 1A & 1D). This is important, as student enjoyment is correlated with improvement in student learning and retention (Blunsdon et al., 2003; Hernik & Jaworska, 2018). Students in all three courses reported increased interest in continuing to learn outside of the classroom (Figure 1C), meeting learning outcome 7 for the project (Table 2). Students also reported satisfaction with making a strong real-world connection to their assignment content (Figures 2A & 2C, Tables 2 & 3), which meets the objectives of learning outcome 4 (Table 2). Taken together, these results suggest that the experiential learning assignments contribute to developing a broader world view and inspire an expanded application of in-course learning.

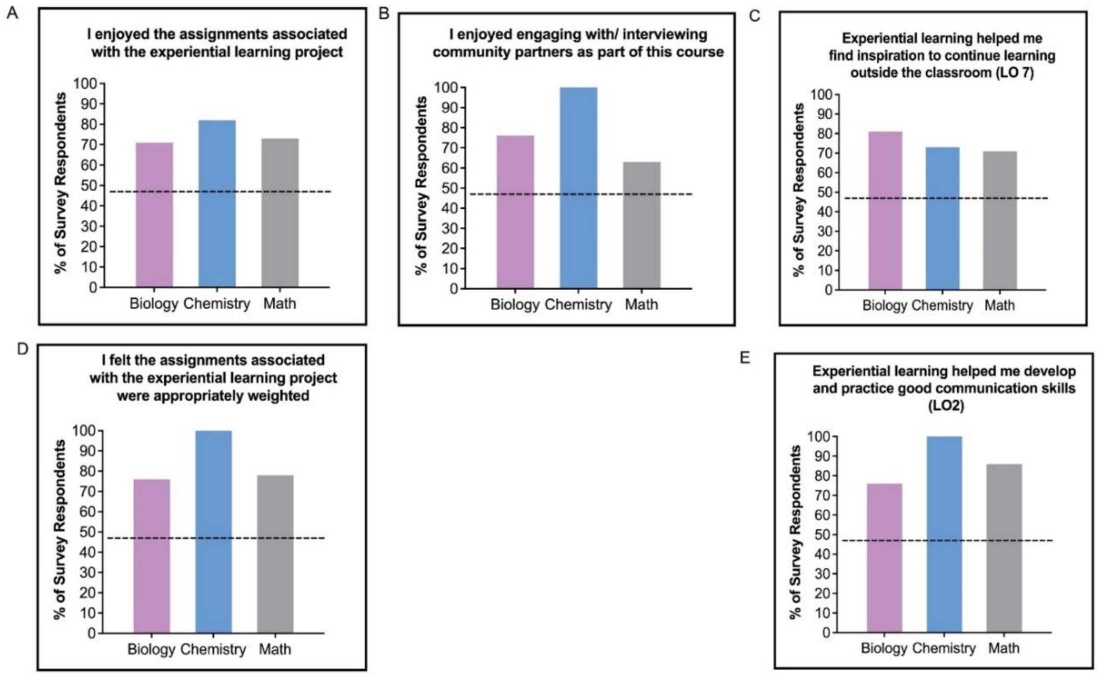
Table 4 provides examples of how student responses to open-ended survey and focus group questions were coded in the various categories depicted in Figure 4. We included student perceptions (positive and negative) as part of the visualization of qualitative feedback (Figure 4). We found that 54% of responses contained positive opinions and 46% highlighted the unique aspect of these assignments in creating real-world connections to their course-based and/or disciplinary learning (Figure 4). Biology and math students were connected to specific community partners with a diverse range of collaboration topics. Students in these two courses reported that these connections did not always result in topics of direct relevance to their specific courses (Figure 3E, Tables 4 & 5). For example, the fourth-year biology course was focused on the molecular mechanisms underlying infectious and genetic diseases. However, some groups worked on resources related to a broader biological concept (e.g., teen sexual health, impact of music on human physiology and well-being). Chemistry students were more readily able to connect their course content to their community partner's area of work, and thus reported the highest level of deepened learning (Figure 3A).

However, focus group discussions (Figure 4) and open-ended survey responses indicated that the experiential learning assignment did help students in the math and biology courses deepen their learning as well (Figure 3A). As students across all three courses reported an enhanced learning experience, this suggests that students perceived educational value in applying their knowledge and skills to communicate a discipline-related topic to those outside their discipline and/or campus community.

Table 2. Survey and Focus Group Questions' Alignment with the Learning Outcomes of Science on the Go.

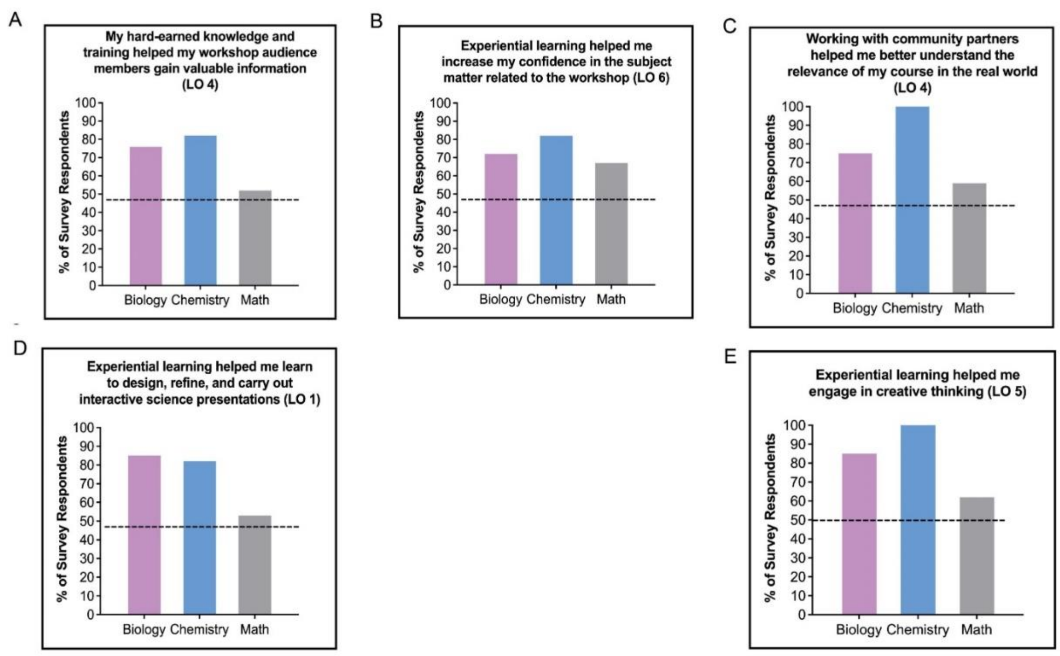
Learning Outcome	Survey Questions	Focus Group Questions
LO 1: Learn to design, refine, and carry out interactive science presentations suitable for members of the public at different levels of expertise, different age groups, and a range of interests from their specific disciplines.	Experiential learning helped me learn to design, refine, and carry out interactive science presentations suitable for members of the public at different levels of expertise, different age groups, etc.	How did the assignment impact the community members you worked with?
LO 2: Develop and practice strong communication skills.	Experiential learning helped me develop and practice good communication skills.	What skills did you gain by completing the project?
LO 3: Develop a strong and collaborative relationship with team members.	Experiential learning helped me develop collaboration skills when working with team members.	What skills did you gain by completing the project?
LO 4: Discover that their academic knowledge and scientific training is applicable outside of academia.	1. Working with community partners helped me better understand the relevance of my course in the real world 2. Experiential learning allowed me to apply my knowledge in a real-world setting. 3. My hard-earned knowledge and training helped my workshop audience gain valuable information.	Did this opportunity help you better understand the relevance of course concepts to your own life?
LO 5: Engage in creative thinking.	Experiential learning helped me engage in creative thinking.	What skills did you gain by completing the project?
LO 6: Enhance their understanding of the disciplinary concepts related to their workshop.	1. Experiential learning helped me increase my confidence in the subject matter related to the workshop. 2. Working with community partners helped me better understand course material. 3. I felt the assignments associated with the experiential learning project helped me deepen my learning.	How has the intentional focus on experiential learning impacted your learning?
LO 7: Find inspiration to continue learning outside the classroom.	Experiential learning helped me find inspiration to continue learning outside the classroom.	N/A

Figure 1. Survey responses: student perceptions of the assignment.



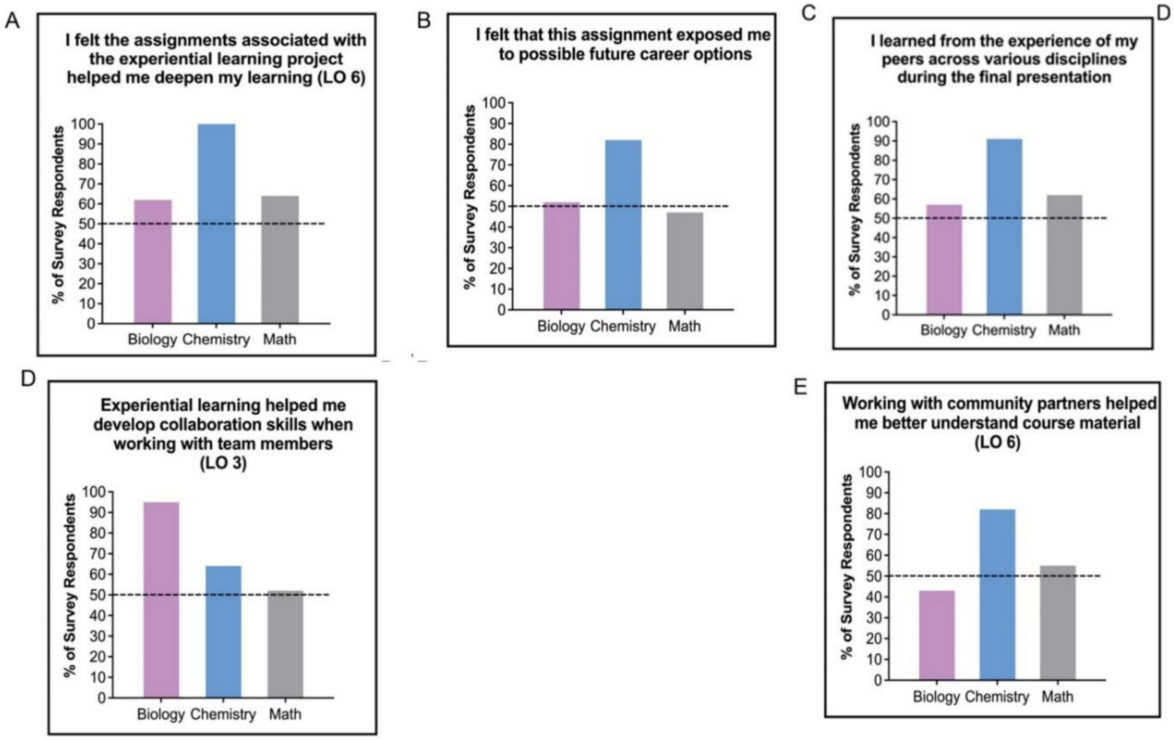
Note: Each figure panel presents the percentage of positive student responses for each of the three STEM courses (rating of 4 or 5; see Methods) for that survey question. The black dashed line represents 50% of respondents. Biology had 21 survey respondents (representative of 55% of course enrolment), Chemistry had 11 survey respondents (representative of 65% of course enrolment), and Math had 22 survey respondents (representative of 44% of course enrolment).

Figure 2. Survey responses: value of assignment and creative skill development.



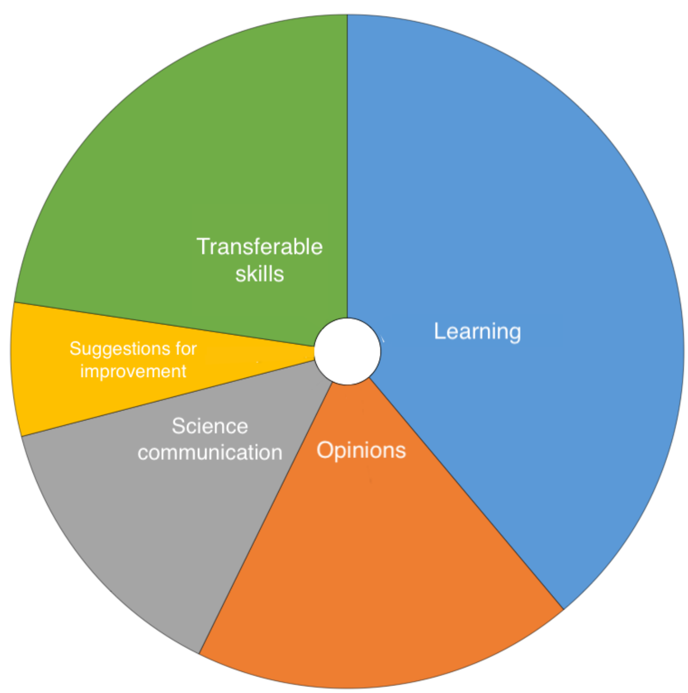
Note: Each figure panel presents the percentage of positive student responses for each of the three STEM courses (rating of 4 or 5; see Methods) for that survey question. The black dashed line represents 50% of respondents. Biology had 21 survey respondents (representative of 55% of course enrolment), Chemistry had 11 survey respondents (representative of 65% of course enrolment), and Math had 22 survey respondents (representative of 44% of course enrolment).

Figure 3. Survey responses: student-reported learning, career exploration, and collaborative skill development.



Note: Each figure panel presents the percentage of positive student responses for each of the three STEM courses (rating of 4 or 5; see Methods) for that survey question. The black dashed line represents 50% of respondents. Biology had 21 survey respondents (representative of 55% of course enrolment), Chemistry had 11 survey respondents (representative of 65% of course enrolment) and Math had 22 survey respondents (representative of 44% of course enrolment)

Figure 4. Hierarchy chart (sunburst diagram) presents the categories into which we coded students' responses to open-ended survey questions and the focus group transcripts.



Notes: The categories were based on the learning outcomes and research questions (pg 4): Student perceptions (positive or negative), Transferable skills (communication, teamwork, creative thinking, other), Learning (course content, real-world connection, other), Science communication (or specifically content creation for members of public), and Suggestions for improvement. The larger the box, the more responses were coded into that category

Table 3. Science on the Go Learning Outcomes that were Met Based on our Study.

Course	Learning Outcomes						
	LO 1 Science communication	**LO 2** Communication	**LO 3** Collaboration	**LO 4** Real World Connection	**LO 5** Creative thinking	**LO 6** Understanding course concepts	**LO 7** Inspiration to keep learning
Biology *BIOD29*	✓	✓	✓	✓	✓	✓	✓
Chemistry *CHMD47*	✓	✓		✓	✓	✓	✓
Math *MATAD02*		✓		✓	✓	✓	✓

Notes: Each learning outcome (LO) was considered met when the majority (>70%) of survey and focus group respondents provided positive responses to the questions designed to probe fulfilment of these LOs.

Table 4. Sample Quotes from Students' Responses that Demonstrate how the Responses were Coded to the Different Categories, as Illustrated by Figure 4.

Analysis Category	**Sample Quotes/Comments**
Positive student perceptions	"I liked working with members of the community." "It felt very independent, and I really enjoyed that."
Negative student perceptions	"Didn't feel relevant to the course"
Creative thinking	"This allowed us to get creative and research different topics and design fun assignments"
Teamwork	"It was overall really engaging working with others as a team."
Communication	"I have learned to voice and communicate my ideas to my peers and gained a little more confidence in speaking."
Science communication	"I liked how we get to make an impact in the community through the scientific skills and knowledge we have learned in this course."
Relation to course concepts	"It made me do additional research about concepts learned in class to further my understanding."
Real world connections	"Very helpful as most times you don't expect to encounter what you learned in class in real life."
Suggestions for improvement	"Difficult to find someone to interview." "It was a bit too open ended and needed more structure to it."

In addition to an enhanced learning experience (Figure 3A), students across all courses found that the experiential learning assignment helped them feel more confident in their knowledge of the topics they worked on (Figure 2B), demonstrating increased self-efficacy. By enhancing their understanding of the concepts related to their workshops, the goals for learning outcome 6 (Table 2) were met. Students in all three disciplines agreed that their disciplinary knowledge could be used to benefit the community (Figure 2A & 2C). This is of particular interest as it has previously been reported that STEM majors often show lower levels of social agency compared to non-STEM majors (Garibay, 2015). Therefore, these types of experiential learning assignments may work towards developing a sense of community responsibility among students across STEM disciplines. Based on student responses, the experiential learning assignment had positive impacts as students reported making real-world connections with their course content and discipline, developing higher self-efficacy, and gaining insights on how they can contribute to their community. As has been reported by other studies, the students' positive perceptions of the assignment may have constructive impacts on their future career goals and retention in STEM (Astin et al., 2000; Billig & Eyler,2003; Brownell & Swaner, 2012; Gallini & Moely, 2003; Jackson & Wilton, 2016; Smith, 2014).

Transferable skill development

We were also interested in understanding the assignment's effect on the development of communication skills (e.g., effective communication with team-members or community partners) and science communication skills (e.g., effective delivery of a workshop to a broad audience on a STEM topic). All three assignments had community partner interactions; chemistry students performed interviews, biology students collaborated with their partners to present a resource to a targeted audience, and math students presented to their partner as well as interviewed them. As part of this interaction, students engaged in oral, written, and social communications with their community partners. It is of significance that 76% of students across all three courses reported enjoying this interaction (Figure 1B) and 84% of students across all three courses reported development of their communication skills through participating in the experiential learning assignment (Figure 1E). This strengthening of communication skills meets the objectives of learning outcome 2 (Table 2). In addition, the open-ended survey responses and focus group discussion analyses demonstrated that the category with the most student responses was transferable skill development (Figure 4). Majority of coded responses (84%) in this category referred to how students appreciated developing skills such as communication and collaboration that would be applicable in future careers. Students also highlighted how they enjoyed interacting with their community and developing skills to communicate science concepts to general audiences, as this helped them understand the value of their coursework outside of the classroom. This meets the objectives of learning outcome 1, 4, and 6 (Table 2). While our study highlights how community interaction through experiential learning assignments can increase both general and science communication skills, other studies have demonstrated that building confidence in science communication skills can also increase engagement with community activities (Copple et al., 2020; Rose et al., 2020). Therefore, it may be that promoting community engagement and communication skills can act in a positive feedback loop, whereby both facets have positive effects on each other.

Intriguingly, self-reported student skill development differed for biology and chemistry students in comparison to the math students. We observed a higher percentage of biology and chemistry students reporting transferable skill development in creative thinking (Figure 2E) and science communication (Figures 2D), compared to math students. Despite the difference in magnitude, we do observe that >50% of respondents across all courses met these learning outcomes (Figure 2D and 2E). Additionally, student responses in open-ended survey questions further affirmed development of these skills (Figure 4; Table 3). This revealed the importance of using open-ended writing to gain further insights on the perceived value of student learning during the assignment. This is in line with studies that suggest assessing learning for experiential learning assignments should not solely rely on grades and rather encompass multiple assessment tools that are more informative about the benefits of the experience (Batchelder & Root, 1994; Kezar, 2002; Rhoads, 1997). Students from all three courses developed strong creative thinking and communication skills (Figures 1E & 2E, Tables 2 & 3). The overall positive reporting on the development of transferable skills meets the objectives of learning outcomes 1, 2 and 5 (Table 2).

Lastly, we note that the biology assignment was the only iteration that required group work. Therefore, we observed a comparatively higher reporting of collaborative skill development among biology students (Figure 3D). Despite biology students not reporting that working with community members enhanced their learning of course material through this assignment (Figure 3E), majority of students (95%) reported being able to learn from their peers (Figure 3C). This aligns with previous findings that group work helps enhance course concept understanding and promote community building, especially in virtual courses (Drouin & Vartanian, 2010; Khan et al., 2017; Pranjol et al., 2022; Robinson et al., 2007). As a result of the required group work in the biology experiential learning assignment, learning outcome 3 was only met in this course (Tables 2 & 3).

Overall, students from all three courses reported developing transferable skills as a result of participating in the experiential learning assignment, which aligns with findings from other experiential learning assignments (Begley, 2013; Gibbs, 2022; Jackson, 2017; Kalas & Raisinghani, 2019; Kulesza et al., 2022; Peters et al., 2014; Pranjol et al., 2022; Robinson et al., 2007).

Table 5. Sample Suggestions Offered by Students to Improve Future Iterations of the Assignments.

Course	Student Suggestions for Improvement
Biology (BIOD29)	Better demonstration of how their project relates to the course content.
	Standardized time commitment, make sure community partners are on same page about expectations and deliverables.
Chemistry (CHMD47)	Provide a list of professors that can be contacted early in the semester and are willing to be interviewed.
	Provide more clarity with the assignment instructions and expectations.
Math (MATAD02)	Screen partner visits or have a TA/Prof present to keep discussion on track.
	More relevance between their assigned topic and the partner's work.

Conclusions

The science on the go assignments made a strong positive impact on students' learning experiences. They reported enjoying the assignment, as it was a unique learning experience compared to other assignments they have worked on in the past. Student responses in all three courses supported fulfillment of most of learning outcomes (Table 3). These findings agree with previous conclusions on the impact of experiential learning assignments on student learning and skill development (Astin et al., 2000; Begley, 2013; Billig & Eyler, 2003; Blunsdon et al., 2003; Kalas & Raisinghani, 2019; Kulesza et al., 2022). Students reported that working with community partners during the assignment also inspired them to continue learning outside of the classroom and volunteer for similar initiatives in the future.

In addition, we also found differences in student self-reporting of learning between STEM disciplines. The differences in enrolment and number of survey respondents in each course could have impacted the divergence in skill development between the different disciplines that we noted by examining students' responses. While math and biology courses had 22 (44% of course enrolment) and 21 (55% of course enrolment) respondents respectively, chemistry had 11 respondents (65% of course enrolment). The learning environment may have also played a role in the differential reporting of skill development. While math students were able to meet with their community partners and present to them in-person; chemistry and biology students had to interact with their community partners virtually. The biology students also had to interact with their group members virtually when managing communication and collaboration to complete their deliverable. In addition, standardizing the assignment structure between courses and ensuring strong overlap between course content and assignment content may help bridge the gaps and divergence in skill development between the different disciplines. In fact, the math course ran a second iteration of the assignment after modifications based on the feedback reported here (Table 5). Community partners were brought in for virtual workshops to help students build geometric models. This change in assignment format and course relevance increased positive reporting of learning course content and identifying real-world applications of course content (personal communication, unpublished results, September 14, 2022).

Based on the findings above, the experiential learning assignments were a beneficial addition to all three STEM courses, as they provided students the opportunity to develop transferable skills for their future careers and connect their knowledge to their community. Comparing across different courses with a similar assignment structure may reveal more discipline-specific trends and highlight differences in how students self-report skill development. This would help identify which forms of experiential learning assignments are more beneficial to specific disciplines. We recommend integrating experiential education in the context of community-partnered projects in undergraduate courses across STEM disciplines, along with integrating methods for students to articulate and reflect in multiple ways on their skill development and future career planning.

Funding

The project was supported by the Dean's Experiential Learning Fund (UTSC).

Acknowledgements

We thank the students from MATAD02 (Fall 2019), CHMD47 (Winter 2022) and BIOD29 (Winter 2022) for their enthusiasm and engagement in the experiential learning assignments. We are grateful to the students who took time to complete the surveys, write thoughtful reflections and participate in the focus groups. We thank the Integrated Learning Experience (ILE) team for their invaluable help with identifying and connecting us to community partners for the assignments in Biology and Math, as well as coordinating partner feedback. We gratefully acknowledge support for this project through the Dean's Experiential Learning (EL) Fund from the Office of the Vice Principal Academic & Dean at UTSC. this study was approved under the REB number 00038372.

Conflict of Interest

The authors have no competing interests to declare.

Author's Contributions

AA, NT and ZS conceptualized and coordinated the study. AJ and TM conducted the focus groups and analyzed the data. AA, TM and AR wrote the manuscript. AA, NT, ZS, AJ, TM and AR edited the manuscript.

References

Astin, A., Vogelgesang, L., Ikeda, E., & Yee, J. (2000). How Service Learning Affects Students. Higher Education. https://digitalcommons.unomaha.edu/slcehighered/144

Batchelder, T. H., & Root, S. (1994). Effects of an undergraduate program to integrate academic learning and service: Cognitive, prosocial cognitive, and identity outcomes. Journal of Adolescence, 17(4), 341–355. https://doi.org/10.1006/jado.1994.1031

Begley, G. S. (2013). Making Connections: Service-Learning in Introductory Cell and Molecular Biology. Journal of Microbiology & Biology Education, 14(2), 213–220. https://doi.org/10.1128/jmbe.v14i2.596

Billig, S. H., & Eyler, J. (2003). Deconstructing Service-Learning: Research Exploring Context, Participation, and Impacts. Advances in Service-Learning Research. Information Age Publishing Inc.

Blunsdon, B., Reed, K., McNeil, N., & McEachern, S. (2003). Experiential Learning in Social Science Theory: An investigation of the relationship between student enjoyment and learning. Higher Education Research & Development, 22(1), 43–56. https://doi.org/10.1080/0729436032000056544

Brownell, J. E., & Swaner, L. E. (2012). Five High-Impact Practices: Research on Learning Outcomes, AAC&U. https://www.aacu.org/publication/five-high-impact-practices-research-on-learning-outcomes-completion-and-quality

Copple, J., Bennett, N., Dudo, A., Moon, W.-K., Newman, T. P., Besley, J., Leavey, N., Lindenfeld, L., & Volpe, C. (2020). Contribution of Training to Scientists' Public Engagement Intentions: A Test of Indirect Relationships Using Parallel Multiple Mediation. Science Communication, 42(4), 508–537. https://doi.org/10.1177/1075547020943594

Drouin, M., & Vartanian, L. R. (2010). Students' Feelings of and Desire for Sense of Community in Face-to-Face and Online Courses. Quarterly Review of Distance Education, 11(3), 147–159.

Freudenberg, B., Brimble, M., & Cameron, C. (2011). WIL and Generic Skill Development: The Development of Business Students' Generic Skills Through Work-Integrated Learning (SSRN Scholarly Paper No. 1851169). https://papers.ssrn.com/abstract=1851169

Freudenberg, B., & Subramaniam, N. (2007). Preparing Accounting Students for Success in the Professional Environment: Enhancing Self-Efficacy Through a Work Integrated Learning Programme. 8.

Gallini, S. M., & Moely, B. (2003). Service-Learning and Engagement, Academic Challenge, and Retention. Michigan Journal of Community Service Learning, 10, 5–14.

Garibay, J. C. (2015). STEM students' social agency and views on working for social change: Are STEM disciplines developing socially and civically responsible students? Journal of Research in Science Teaching, 52(5), 610–632 https://doi.org/10.1002/tea.21203

Gibbs, T. N. (2022). Using Experiential Learning to Create an Inclusive Classroom, Promote Equity, and Develop Professional Identity (SSRN Scholarly Paper No. 3996474). https://doi.org/10.2139/ssrn.3996474

Hernik, J., & Jaworska, E. (2018). THE EFFECT OF ENJOYMENT ON LEARNING. 508–514. https://doi.org/10.21125/inted.2018.1087

Jackson, D. (2017). Developing pre-professional identity in undergraduates through work-integrated learning. Higher Education, 74(5), 833–853. https://doi.org/10.1007/s10734-016-0080-2

Jackson, D., & Wilton, N. (2016). Developing career management competencies among undergraduates and the role of work-integrated learning. Teaching in Higher Education, 21(3), 266–286 https://doi.org/10.1080/13562517.2015.1136281

Kalas, P., & Raisinghani, L. (2019). Assessing the Impact of Community-Based Experiential Learning: The Case of Biology 1000 Students. International Journal of Teaching and Learning in Higher Education, 31(2), 261–273.

Kezar, A. (2002). Assessing Community Service Learning: Are We Identifying the Right Outcomes? About Campus, 7(2), 14–20. https://doi.org/10.1177/108648220200700204

Khan, A., Egbue, O., Palkie, B., & Madden, J. (2017). Active Learning: Engaging Students to Maximize Learning in an Online Course. Electronic Journal of E-Learning, 15(2), 107–115.

Kulesza, A. E., Imtiaz, S., & Bernot, K. M. (2022). Building Connections to Biology and Community through Service-Learning and Research Experiences. Journal of Microbiology & Biology Education, 23(3), e00082-22. https://doi.org/10.1128/jmbe.00082-22

Peters, J., Sattler, P., & Kelland, J. (2014). Work Integrated Learning in Ontario's Postsecondary Sector The Pathways of Recent College and University Graduates [Higher Education Quality Council of Ontario]. https://heqco.ca/pub/work-integrated-learning-in-ontarios-postsecondary-sector-the-pathways-of-recent-college-and-university-graduates/

Pranjol, M. Z. I., Oprandi, P., & Watson, S. (2022). Project-based learning in biomedical sciences: Using the collaborative creation of revision resources to consolidate knowledge, promote cohort identity and develop transferable skills. Journal of Biological Education, 0(0), 1–17. https://doi.org/10.1080/00219266.2022.2147576

Pretti, T. J., & Fannon, A. (2018). Skills articulation and work integrated learning. Driving Academic Quality: Lessons from Ontario's Skills Assessment Projects. Higher Education Quality Council of Ontario, Toronto. https://wilresearch.uwaterloo.ca/Resource/View/3065

Rhoads, R. A. (1997). Explorations of the Caring Self: Rethinking Student Development and Liberal Learning. https://eric.ed.gov/?id=ED408549

Robinson, F., Wuetherick, B., Wolanski, N., & Greenwood, S. (2007). Building Core Animal Science Knowledge through Project-Based Study. NACTA, 51, 33–36.

Rose, K. M., Markowitz, E. M., & Brossard, D. (2020). Scientists' incentives and attitudes toward public communication. Proceedings of the National Academy of Sciences, 117(3), 1274–1276. https://doi.org/10.1073/pnas.1916740117

Smith, C. (2014). Assessment of student outcomes from work-integrated learning: Validity and reliability. Asia-Pacific Journal of Cooperative Education, 15, 209–223.

Veldman, J., Van Laar, C., Thoman, D. B., & Van Soom, C. (2021). "Where will I belong more?": The role of belonging comparisons between STEM fields in high school girls' STEM interest. Social Psychology of Education, 24(5), 1363–1387. https://doi.org/10.1007/s11218-021-09663-6

Whitcomb, K. M., Kalender, Z. Y., Nokes-Malach, T. J., Schunn, C. D., & Singh, C. (2020). Comparison of Self-efficacy and Performance of Engineering

Undergraduate Women and Men.Wong, B., Chiu, Y.-L. T., Murray, Ó. M., Horsburgh, J., & Copsey-Blake, M. (2023). 'Biology is easy, physics is hard': Student perceptions of the ideal and the typical student across STEM higher education. International Studies in Sociology of Education, 32(1), 118–139. https://doi.org/10.1080/09620214.2022.2122532

Wyss, V. L., & Tai, R. U. (2012). Service learning in high school biology and college major choice. College Student Journal, 46(2), 459–465

APPENDIX

Survey questions:

Engaging with community partners: This section of the survey asks you about your experience working with different community partners as part of your course experiential learning assignment.

1. I enjoyed engaging with / interviewing community partners as part of this course.
2. Working with community partners helped me better understand course material.
3. Working with community partners helped me better understand the relevance of my course in the real world.
4. Any other comments about what you learned from interacting with community partners?

Associated course work: This part of the survey asks you about any course assignments you completed in relation to the experiential learning project (i.e. reflections, presentations, etc.)

5. I enjoyed the assignments associated with the experiential learning project (i.e. Reports, presentations, reflections, etc.).
6. I felt the assignments associated with the experiential learning project helped me deepen my learning.
7. I felt the assignments associated with the experiential learning project were appropriately weighted (as in the percentage value assigned to each assignment on the syllabus).
8. Any other comments about assignments associated with the experiential learning project?

Skills Learned: This part of the survey asks you about skills you may have learned as a result of the experiential learning assignment on the whole.

9. Experiential learning helped me learn to design, refine, and carry out interactive science presentations suitable for members of the public at different levels of expertise, different age groups, and a range of interests.
10. Experiential learning helped me develop and practice good communication skills.
11. Experiential learning helped me develop collaboration skills when working with team members.
12. My hard-earned knowledge and training helped my workshop audience members gain valuable information.
13. I learned from the experience of my peers across various disciplines during the final presentation.
14. Experiential learning helped me strengthen my public speaking skills.
15. Experiential learning helped me engage in creative thinking.
16. Experiential learning helped me increase my confidence in the subject matter related to the workshop.
17. Experiential learning helped me find inspiration to continue learning outside the classroom.
18. Experiential learning allowed me to apply my knowledge in a real-world setting.
19. I felt that this assignment exposed me to possible future career options.

Overall Perceptions: This portion of the survey asks you about overall thoughts you have about the experiential learning assignment and any other final thoughts.

20. Overall, I enjoyed the experiential learning assignment.
21. What were some of the strengths or things you liked about this assignment?
22. What were some weaknesses or things you didn't like about this assignment?

Focus group questions:

Introductions:
1. Please state your name, year of study, and what program you are in.
2. What were the reasons you decided to take this course? (Probe for: motivation, goals, intentions)
    a. Did you know about the experiential learning component in this course before you enrolled? If so, was this a factor which helped you decide whether to enroll for this course or not?
3. Can you describe the experiential learning you engaged in and the project you completed in this course? (Probe for: who the community partners were, what was the work that transpired)

Perceptions of the Program:

1. What are your overall impressions of the experiential learning component in this course? How does this compare to your previous learning experiences? (i.e. experience with other courses).
2. What were the components of the experiential learning program that made it a success? Were there any factors that made it unsuccessful?
3. What do you think were the greatest challenges throughout the experiential learning program? What can we do to address these challenges next time?

Special Topics:

1. How has the intentional focus on experiential learning impacted your learning? How did it impact the community members you worked with? (Probe for: engagement, making real-world connections, any positive/negative feelings, impact on learning, relationships with educators, relationships with community, meaning making/relevancy of curriculum, workload, etc.)
2. What skills did you gain by completing the experiential learning project? (Probe for: global competencies like communication skills, collaboration skills, etc.)
3. Did this experiential learning opportunity help you better understand course concepts and their relevance to your own life? (Probe for: real-world learning, love of subject, career exploration, etc.)

Conditions and Recommendations:

1. What do you think are the conditions or factors for the success and effectiveness of this program? (Probe for: educator support, course design, community liaisons, community partners, prior skillset, etc.).
2. What would be your suggestions for things we should keep, do away with, or revise in future iterations of this program? (Probe for: assignment structure, timelines, etc.).

Wrap Up:

1. Is there anything that we didn't cover today that you would like to add?

Community partner questions:

1. What are your overall impressions of this outreach program? How does this compare to other instances when you facilitated partnerships with other institutions?
2. What do you think are the conditions or factors for the success and effectiveness of this program? Please tell us about some of the successes that you identified of this experiential learning program.
3. What would be your suggestions for things we should keep, do away with or revise in the future iterations of this program. Please tell us about any challenges that you identified with this experiential learning program.
4. In your opinion, how did the experiential learning opportunity impact development of students' communication skills, collaboration skills or any other transferable skills.
5. Please provide us with your reflection on this statement: This experiential learning opportunity engaged students and inspired them to pursue learning in this area outside the classroom/explore careers in this subject matter.
6. Is there anything else you would like to add?

Mystery Encourages Engagement and Interest in Plants

Aditi Sinha, Ph. D

Biology Program
Loras College
Dubuque, IA 52001
Aditi.sinha@loras.edu

Abstract

Active learning pedagogies offer opportunities to increase student engagement and interest in plants. The Mystery Plant Project is a hands-on, semester-long active learning pedagogy I developed for an introductory, undergraduate Plant Biology course. Students investigate various aspects of their mystery plant species using observations, and knowledge and skills acquired through lectures and laboratory sessions. The culmination of this inquiry involves identification of the mystery plant. During the first week, students receive unidentified seeds they germinate and grow in the greenhouse for 14-15 weeks. Students are responsible for determining what to examine and how, interpreting their observations, and their projects' endpoint. The course's structured and scaffolded lecture and laboratory components support student progress on the project. In addition to a comprehensive paper describing their plant's botany, students share their findings in a creative presentation. Students value the hands-on reflective learning approach, practical application of their newfound knowledge, the opportunity to take ownership of their learning, and their enhanced plant awareness. This pedagogical approach offers instructors an alternative strategy to enhance student engagement and curiosity about plants. It can be a valuable tool to address plant awareness disparity and can be integrated into any undergraduate Plant Biology course.

Keywords: active learning, plant biology, plant awareness, plant awareness disparity.

Introduction

The established benefits of active learning pedagogies encompass enhanced understanding and retention of the subject material, increased participation, peer collaborations and application (Allsop et al., 2020; Freeman et al., 2014; Lemelin et al., 2021; Lumpkin et al., 2015). Active learning pedagogies, that allow students to engage and connect with the material, can potentially serve as valuable tools in addressing components of Plant Awareness Disparity (PAD).

PAD continues to be a concern among plant biology educators. It describes the tendency of individuals to overlook plants and not acknowledge their importance to human society. PAD has 4 components that are interconnected: disproportionately low levels of attention to plants than animals, an attitude that plants do not matter, low levels of plant knowledge, and therefore, low relative interest in plants (Parsley, 2020; Wandersee & Schussler, 1999). Various proposed approaches to address PAD include place-based botany education, introduction to biodiverse environments, engagement with plants, and caring for plants (Krosnick et al., 2018; Pany et al., 2019; Stagg & Dillon, 2022). Stagg and Dillon (2022) suggest frequent interactions between individuals and plants that have everyday relevance enhances plant awareness.

Here, I describe a student-centered, active learning pedagogical approach, the Mystery Plant Project (MPP), that offers opportunities for students to interact with plants, thereby fostering engagement, interest and awareness about plants. The objective of the MPP is for students to investigate various biological aspects of a mystery plant (MP) species using semester-long observations, as well as knowledge and skills acquired from lecture and laboratory sessions. The element of mystery in the project sparks student curiosity and encourages further engagement with the material. In addition to promoting active learning, this inquiry-based pedagogy fosters reflective and critical thinking skills in students as they are required to interpret their observations of the MP and cannot generically apply concepts they learn in class. Furthermore, the MPP helps students build important soft skills such as enhanced observation abilities, and transfer of knowledge and understanding from one context to another.

The MPP is a hands-on, semester-long collaborative laboratory project that I have integrated into my 200-level undergraduate Plant Biology course. During the first laboratory session, students receive mystery seeds that they germinate and grow for

14-15 weeks in the departmental greenhouse. Using the knowledge and skills gained in lectures and laboratory sessions throughout the semester, students are responsible for determining what to examine, how to examine, interpreting their observations, and the endpoint of their project. This non-prescriptive nature of the project requires students to be creative, stay actively engaged and take ownership of their learning. Student investigations span an array of topics such as structure, growth, reproductive biology, ecology, and economic botany of their MP. The culmination of the project involves the identification of the mystery plant during the last two weeks of the semester.

The focus of this project and student' observations of their plants can be adjusted to align with the learning objectives of the course this project is integrated into.

The MPP can be integrated into any undergraduate level plant biology course. Students in my Plant Biology course are all biology majors and range from sophomores to seniors. Most of these students are pursuing a health science career and have had limited exposure to plant sciences, and typically low levels of interest in plants. As all the MP species are economically important, the MPP piques students' curiosity to further investigate the relevance of plants in their lives, one of the underlying themes of my course.

Activity

The instructor's pre-laboratory preparation entails ordering seeds earlier in the summer as seeds tend to get sold out. The primary selection criteria for MP are: (i) seed germination within a week, and (ii) flowering within 8-10 weeks of sowing. Over the course of the years, I have experimented with various annual plant species and have found that many cultivars of ornamental and edible plants satisfy these criteria and can be easily purchased from local garden stores or online. Plants that have worked well are species of: *Tagetus*, *Zinnia*, *Petunia*, *Salvia*, *Mimulus*, *Ocimum basicilicum* available from Park Seed (www.parkseed.com) as well as *Phaseolus* (use a bush variety), *Pisum (snow peas and peas)*, *Coriandrum sativum*, *Cucumis sativus*, and *Anethum graveolens* available from Jung Seeds (www.jungseed.com). Some culinary herbs used for the MPP do not flower within the 8-10 week timeframe. Since many of these herbs are grown in our college's community garden, students can use flowers and fruits from these plants to observe reproductive biology and identify the species. If this option is unavailable, the instructor can grow these plants prior to the start of the semester to ensure they flower during the semester. For a MP species that flowers within 4-5 weeks, it is optimal to plant it in two batches since students may not yet have the expertise to identify the species. As such, students can plant half the seeds during the first week of the semester and the remaining during week 4 or 5. Additionally, using bush varieties or non-trailing varieties of the species can also conserve greenhouse space. Approximately 10-12 seeds of any given MP species are placed in a glass vial, along with germination and growth instructions (I cut the instructions on the seed packets to include with the vials, ensuring that the identity of the plant is not revealed). Each vial is assigned a unique number and wrapped in aluminum foil to keep the seeds in darkness. The vials are stored in a cool, dry environment. The instructor should save seeds of each MP species in the event that students need to grow more plants. Table 1 provides a comprehensive timeline of the MPP.

Table 1. MPP timeline and planning

Time and duration	Activity and Description
Prior to week 1; 30-60 min	• Order seeds. • Acquire supplies: potting soil, pots, trays to place pots in and plastic wrap. • Put seeds in numbered vials; include germination instructions. Store in a dark, cool, dry place.
First laboratory session; 1.5-2 hrs	• Start the MPP. • Planting demonstration. Students plant seeds.
~Week 10	Students submit MP paper outline.
~Week 11	Students submit creative presentation plan.
Week 12-14	• Students identify their MP. • Instructor confirms plant identity. Gives cultivar name to each group.
Last laboratory session	Creative presentations.
Last week	Notebook, paper and peer evaluation are due.

During the first lab session, I explain the premise of the MPP, the learning objectives and how it fits into the larger context of the learning outcomes of the Plant Biology course and the Biology Program at Loras College. Ideally, students work in pairs (or in groups of three based on the number of students in lab). Each group has a unique mystery plant species. They select a vial of seeds. The instructor should record the vial number for each group. As most students have little to no plant experience, the seed planting process is demonstrated in the greenhouse. Students are encouraged to sow 6-8 seeds (one seed per pot) which provides them with a safety net in case of plant mortality from disease or pests. All plants can be grown in 10-15cm diameter pots depending on their stature and growth form. As the identity of the plants is only known to the instructor, pots need to be assigned to each group. All required materials are provided to the students. Students grow the plants in the departmental greenhouse for about 14-15 weeks. During the first laboratory session, it is important to discuss plant care and troubleshooting (e.g., detecting pests and diseases, too much or too little watering etc.).

As this is a semester long project, we engage in class discussions to define effective collaboration and establish reasonable expectations for project partners. We create a bulleted list on the whiteboard which sets up the expectations for the entire semester. The pre-laboratory lecture, demonstration and planting take about 1.5-2 hours. In a 3-hour laboratory period, as in my case, I use the last hour of the first laboratory session for a short fun activity, such as a plant scavenger hunt outside.

Students are encouraged to monitor their plants and record observations at least once a week. However, they often opt to do so on Mondays, Wednesdays, and Fridays, the days when lecture class meets. Given that this is an open-ended project, students determine what to observe and explore using the knowledge and skills acquired throughout the semester. They are encouraged to record observations from the day they receive their seeds and maintain a running list of themes/aspects of the MP that can be explored further. Some such themes/aspects maybe, but not limited to, morphology, anatomy, reproductive biology, behavior, ecology, economic- and ethnobotany, and taxonomy. Students are encouraged to be adaptive and creative. For instance, if their plant is a nitrogen-fixer or gets infested with pests during the semester, students can make observations relevant to these themes. Diseases and pests can be a good segue into secondary compound defenses of their MP. The instructor's role should be to facilitate the inquiry.

Students will require guidance to identify their MP species using Gleason and Cronquist (2014). Ideally, students would have been introduced to plant taxonomy and using dichotomous keys in earlier labs in the course. I typically have a dedicated laboratory session towards the last third of the semester for students to work on the MP identification. To facilitate the identification process, I help each group determine the appropriate section key in the manual (some will accomplish this without any assistance); they then identify, either on their own or with minimal assistance, the family, genus and the species using the manual. For plant families with artificial genera keys or group keys, the instructor may need to provide additional support based on the group's capabilities and the plant family involved (for e.g., more assistance may be required for plants in the Asteraceae family). Students identify their MP either to the species level if their species is listed in the manual or to the family/ genus level. In the latter case, students use reliable internet sources such as e-floras

(https://www.missouribotanicalgarden.org/plant-science/plant-science/about-science-conservation/resources-databases/herbarium)

to determine their species' identity. Remarkably, most of the ornamental plant and culinary herb cultivars used in the MPP can be identified using Gleason and Cronquist (2014). Regardless of the identification process, students must provide evidence of how they determined their species' identity. I typically have each group show me the series of dichotomous statement used (e.g. 1b – 2a etc.). Alternatively, this evidence can be part of their paper if time is a constraint. The instructor could also choose to observe students using the dichotomous keys for their identification for credit. Finally, after verifying the identity, I give them their cultivar name. Each group can then conduct research on the ecology, economic botany and secondary compounds of their MP.

Support and scaffolding should be provided throughout the semester. For instance, the topics covered in my lecture and laboratory sessions provide ideas for observations and allow students to apply knowledge and understanding acquired during the semester to their MP. Typically, the sequence of topics covered in lecture coincide with the growth and development of the MP. Various laboratory activities that students engage in are similar to those they can perform with their MP. For instance, they learn various techniques such as free-hand sectioning, extraction of phytoliths, and examine the morphology, anatomy, and reproductive biology of other plants, that they can apply to their MP. During laboratory sessions that focus on the above-mentioned topics, time is set aside for students to work on their MP. Furthermore, my flipped classroom pedagogy in lecture provides opportunities to tailor several in-class activities to application of lecture concepts to their MP. If more guidance is needed, a laboratory session can be dedicated to working on the MPP towards the end of the semester.

Given that this is a semester-long project, it is crucial to incorporate frequent check-ins throughout the semester. These can be informal (e.g., a brief meeting with each group at the end of a laboratory session during weeks 4-5) or formal (e.g., an outline of the paper and plans for the creative presentation, Appendix A, Table 1). I have found formal check-ins to be valuable in keeping students on task and proving me feedback about where each group is, and the support they need. Alternatively, the check-ins can be conducted as short presentations by each group to share their progress. As students also work on their MPP outside of the lab time, they should have access to materials and stains required for anatomical sections. They should be provided with laboratory safety instructions especially when using stains and razor blades for free-hand sectioning.

In this digital era, where information is readily available, it can be challenging for students to resist using plant identification apps to identify their MP during the initial stages of the project or use the internet as a primary source of information about their plant instead of their observations. Over the fifteen years that I have offered the MPP, I have discovered that clear communication of the project premise, my expectations, and rules for using the internet/AI keeps the mystery in the project. Students are respectful of "the journey is more important than the destination". They are also frequently reminded that the MP identification is just one facet of the project.

Assessment

The assessment of the MPP is based on an observation notebook, paper, creative presentation, and peer evaluation. A detailed description and weighting of each component is included in Appendix A. The observation notebook is a log of all observations a group makes, starting with the day the seeds are sown until the end of the project. It can include drawings, photographs, quantitative data etc. As students' plant knowledge grows, they can revisit their notes to reinterpret their observations. Over the years of offering the MPP, the observation notebook has evolved from a paper notebook to a digital Word document; typically, students will draw diagrams on paper or on their tablets and include them in the Word notebook. I have observed that allowing Gen Z students the freedom to use technology enhances their engagement. However, the instructor may choose to require the submission of a paper notebook.

The goal of the paper is for students to demonstrate an in-depth understanding of their MP's biology and to effectively apply knowledge and skills acquired in lecture and laboratory sessions. It includes labeled images (e.g., photographs, micrographs, diagrams) as evidence of student observations and effort. The paper is typically organized by botanical themes such as growth form and life span, morphology (roots, stems leaves), anatomy, reproductive biology (flower structure, pollination, seed dispersal and germination). However, organization and format are not prescriptive. It is important to communicate to students that the paper should be based on their observations alone, except for their research on economic and ethnobotany, taxonomy and ecology.

The creative presentation is a way for students to showcase their MP in a fun way using their creative abilities (Appendix A). This assessment component was implemented several years ago in response to student feedback. Given that the creative component of the presentation is 3-4 minutes long, it may not capture all aspects and visuals of the MP. As such, students include a brief PowerPoint presentation to share images. The entire presentation is 8-10 minutes long. Students are assessed based on the rubric in Appendix B which is provided to the students during the first week. Creative presentations in the past have included a skit, children's book, poetry slam, haiku, short documentary, museum tour, cooking show, and live musical performances, to name a few. Additionally, students assess the contribution and work ethic of their MPP through a peer evaluation that is accessible to the instructor alone (Appendix C). Peer evaluation accounts for 5% of the MPP grade.

Discussion

The semester long MPP project is designed to foster student interest in and engagement with plants and promote active learning. The process of observing and applying course material towards describing the MP further enhances two important soft skills, required of students in the sciences: (i) making observations, and (ii) transferring and applying knowledge and skills from one context to another rather than compartmentalization of information. Additionally, it provides opportunities to further enhance reflective and critical thinking skills as students are required to connect what they know with their observations. Such active engagement with course material enhances student thinking, understanding and retention (Lumpkin et al., 2015). The open-ended nature of the MPP provides students creativity in determining their project's direction. A balance of creativity and structure nurtures learning (Lemelin et al., 2021;Lumpkin et al., 2015).

In my 15 years of offering the MPP, I have experimented with various project iterations. The version described here best compliments the flipped classroom pedagogy of my course and accommodates the maximum of 20 students in the laboratory setting. However, the project offers flexibility in how it can be adopted. For example, the creative presentation component may be excluded. Alternatively, the oral presentation can be expanded to include all aspects of the MP observed, eliminating the need for a written paper. The project can also be scaled up to work in larger-sized laboratories or for multiple laboratory sections using a similar approach of adopting parts of the project. While the creative presentation adds a fun element for the students and the instructor, it is not a critical element, especially, if there are various other opportunities for developing oral presentation skills in the four-year curriculum. For several years, I offered this project without the creative piece which was just as effective. One potential challenge with multiple laboratory sections could be inadequate greenhouse space. To address this, students could work in groups of three instead of two, which would also make the instructor's workload more manageable. The relative weighting of the various MPP components can also be modified.

Overall, student feedback over the years, indicates that most students value the hands-on opportunities to deeply engage with the material. These opportunities range from growing plants to applying knowledge and skills acquired during the semester to investigate their MP. A recurring theme in student feedback is the opportunity to reflect on their learning and understanding. Table 2 gives a representative sample of student feedback. However, the outcomes the MPP have not been quantified.

In addition to meeting the MPP objectives, this active learning approach offers students an opportunity to be more excited about and invested in plants. Students can take ownership of their project and build a connection with plants through the process of growing and observing them. Some students are surprised by their ability to keep their plants alive throughout the semester and take pride in it. They

Table 2. Typical End of the semester Student Feedback on the MPP from Across the Years

"The mystery plant project was very helpful, and I think that it really gave me a better understanding of all of the plant parts that we learned throughout the semester. It is sort of a daunting task at first because it seems like so much, but it is really not nearly as bad as it seems. I really ended up liking it!"
"the Mystery Plant Project was probably one of my favorite projects I have done as a science major!It made me reflect on the course material more than I probably would have if I didn't have to do the project"
"It allowed me to really think outside the box and it allowed me to use hands-on methods to come to a conclusion. It really helped with my problem solving skills and it was amazing to see how everything tied together."
"it put me in the driver seat and use what I learned to my fullest extent for once and I enjoyed the whole process."
"I was able to learn things outside of class on my own time and apply them to concepts within class. Also led me to think about real life applications of botany."
"It taught me how to look at plants in a completely different way. I am now able to tell people how plants grow, their compounds, how their set up, etc."

have, subsequently, bought plants from garden centers. Others are reminded of their childhood experiences gardening with their parents. Students frequently appreciate the practical application of the knowledge they are acquiring. The project sparks curiosity and excitement, with students reporting that they notice things about plants when walking outside that they previously overlooked, or that they can share, with their friends and family, their newfound knowledge of plants. The MPP offers instructors an alternative approach for making botany more engaging to students who might otherwise edit plants out of their daily lives.

Acknowledgements

I would like to thank my colleagues in the Biology Program, Loras College for their support and students who have participated in the MPP over the years. Their valuable feedback has helped in shaping and refining the MPP.

References

Allsop, J., Young, S. J., Nelson, E. J., Piatt, J, & Knapp, D. (2020). Examining the Benefits Associated with Implementing an Active Learning Classroom among Undergraduate Students. International Journal of Teaching and Learning in Higher Education, 32(3), 418-426.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences of the United States of America, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Gleason, H.A., & Cronquist, A. (2014). Manual of Vascular Plants of Northeastern United States and Adjacent Canada. 2nd ed. New York Botanical Garden.

Krosnick, S. E., Baker, J. C., & Moore, K. R. (2018). The pet plant project: Treating plant blindness by making plants personal. The American Biology Teacher, 80(5), 339–345. https://doi.org/10.1525/abt.2018.80.5.339

Lemelin, C., Gross, C. D., Bertholet, R., Gares, S., Hall, M., Henein, H., Kozlova, V., Spila, M., Villatoro, V., & Haave, N. (2021). Mitigating Student Resistance to Active Learning by Constructing Resilient Classrooms. Bioscene, 47(2), 3-9. https://www.acube.org/wp-content/uploads/2022/02/Bioscene-December-2021-20.pdf#:~:text=Volume%2047%20(2)%20December%202021%20Lemelin%20et%20al.:%20Mitigating%20Student

Lumpkin, A., Achen, R. M., & Dodd, R. K. (2015). Student perceptions of active learning. College Student Journal, 49(1), 121–133.

Pany, P., Lörnitzo, A., Auleitner, L., Heidinger, C., Lampert, P., & Kiehn, M. (2019). Using students' interest in useful plants to encourage plant vision in the classroom. Plants, People, Planet, 1(3), 261–270. https://doi.org/10.1002/ppp3.43

Parsley, K. M. (2020). Plant awareness disparity: A case for renaming plant blindness. Plants, People, Planet, 2(6), 598–601. https://doi.org/10.1002/ppp3.10153

Stagg, B.C., & Dillon, J. 2022. Plant awareness is linked to plant relevance: A review of educational and ethnobiological literature (1998–2020). Plants People Planet, 4(6), 579–592. https://doi.org/10.1002/ppp3.10323

Wandersee, J. H., & Schussler, E. E. (1999). Preventing plant blindness. The American Biology Teacher, 61(2), 82–86. https://doi.org/10.2307/4450624

Student Success in a Mixed-Major Animal Behavior Course

Sarah Fauque

University of Louisville, Louisville, KY.

Abstract

Small institutions struggle to balance class size with financial feasibility, leading to canceled electives due to low enrollment. This study reports the preliminary data of a mixed-majors class intended to overcome the minimum enrollment hurdle. Animal Behavior was an upper-level course emphasizing engagement and shared learning. I examined graded assignments and student attitudes to determine if major or scientific background impacted student success. Participating students were evenly distributed across biology (n=9) and psychology (n=10) majors with similar median GPAs (3.8 vs 3.5, respectively). Major was the only predictor of final score (f(1) = 5.69, p = 0.04). While there was a significant difference in final scores between the majors (biology $\bar{x}$ = 93.29 ± 1.61 vs psychology $\bar{x}$ = 83.77 ± 2.88; t(18) = 2.80, p = 0.01), there was no difference in passing the class (final grade ≥ 70%; $X^2(1,19) = 0.95$, p = 0.33). Most students tended to respond more favorably in the final survey than the midterm survey, but biology majors tended to have a greater change in scores than psychology majors. Overall, these data suggest that an upper-level science elective can be successful for mixed-major cohorts, but replication is necessary to draw robust conclusions.

Introduction

The close learning environment of a small campus is often a selling point when recruiting potential students. Compared with large classes, small class sizes contribute to increased student success and graduation rates (Millea et al., 2018). Many institutions employ a minimum enrollment policy under which a class will only run if it is financially feasible. When small class sizes are due to the size of the program or institution, it can be challenging to meet the minimum enrollment requirement to run elective courses. This becomes particularly difficult when electives have prerequisite courses. This type of class cancellation often occurs at the beginning of the semester, causing students and faculty to scramble for another course to fill their schedule. While this experience is likely encountered across higher education, it is often experienced in small colleges and academic programs.

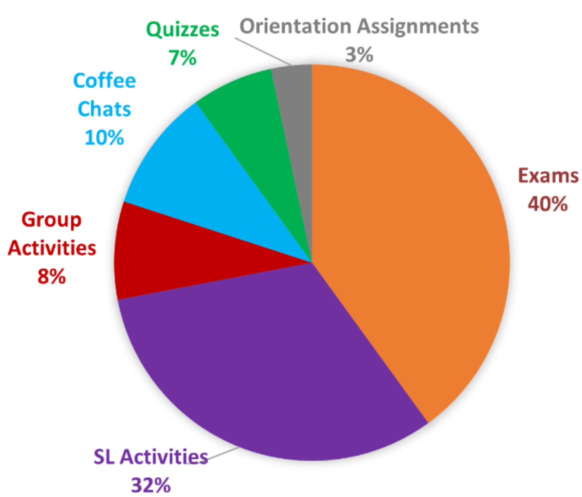
Some institutions take a proactive approach to address the frustrations of course cancellations by carefully tailoring their course offerings so that certain courses are only available in specific years to create a larger student pool with multiple cohorts of prepared students. This requires careful planning and scheduling to ensure courses do not compete for enrollment, causing students to miss out on a class that would benefit their future careers. It also imposes barriers for students who transfer or have changed majors and are not entering the suggested sequence of courses. Another solution developed by some institutions is to open historically low-enrollment elective courses to multiple majors. This solution also introduces new challenges, particularly for the instructor, due to the various student backgrounds. While some students will have a firm grasp of one concept, others will hear it for the first time. Effective teaching in these courses requires the instructor to meet students where they are by getting to know them and supporting their unique needs (Schouten, 2017).

Here, I report on the developed curriculum and preliminary student data of a mixed-major class intended to overcome the minimum enrollment hurdle. Animal Behavior was an upper-level course offered at a small liberal arts college in south-central Kentucky. This institution has historically had difficulties meeting the minimum enrollment threshold for upper-level biology electives; thus, Animal Behavior was open to all students of at least Junior standing. This sets it apart from other animal behavior courses in Kentucky and offers a unique opportunity for all students, regardless of major, to explore behavioral biology.

Course Design

Animal Behavior was designed with an emphasis on engagement and shared learning. Student-centered syllabi have been shown to set a positive tone for a course, and using friendly, descriptive language can increase student-faculty rapport (Richmond et al., 2016). In a mixed-major course, building a relationship of mutual respect is essential to foster a supportive learning environment and meet students where they are (Schouten, 2017). Thus, a student-centered syllabus sets the stage for future interactions and expectations. This is further supported by activities early in the semester designed to focus on forming relationships within the cohort and fostering a trusting environment. Lectures were punctuated with small group discussions, think-pair-share activities, and clicker questions so that students could bring their unique perspectives and claim space in the classroom (Schouten, 2017). Approximately half (47%) of the final grade was determined by content-heavy assessments such as quizzes and exams, and skills-heavy assessments determined the remaining 53% (Figure 1).

Figure 1: Graded course activities were divided into content-heavy (47%) and skills-heavy (53%) assessments. Content-heavy assessments are quizzes and exams that focus on critical concepts. Skills-heavy assessments practice building transferrable skills like teamwork, communication, and scientific literacy.



The content of Animal Behavior was divided into four modules. The first module introduced students to the learning management system and various assignments they would see throughout the semester. Practice assessments increase student performance and are recognized as highly effective learning strategies (Sly, 1999; Biwer et al., 2020), so I leveraged this as we began the semester. The remaining three modules explored the specifics of behavioral biology with a mix of low-stakes and high-stakes assessments modeled after the assessments students practiced in Module 1. Each module also included a quiz before the exam as a practice test to inform students which material needed further study.

The skills-heavy assessments focused on communication through Scientific Literacy (SL) paper discussions and Coffee Chats. Critically reviewing scientific literature can be daunting regardless of major. From informal conversations, students feel they should already know how to review technical articles even when they have no practical experience and assume that this is a skill they will intuitively acquire when they finish their degrees. Often, students become discouraged when they struggle to read this literature for the first time. SL paper discussions demonstrate that deep knowledge is not a prerequisite when starting a project but rather the curiosity and drive to understand and explore a field. The knowledge develops organically through the exploration of the topic and by finding answers to their questions.

SL paper discussions critically review classic and contemporary ethological literature over a selected topic in the semester. When preparing for the discussion, students followed a template that mirrors my experience in exploring new topics. It encouraged students to note content that was confusing—terms, methods, statistics— and modeled how to reduce their confusion by researching the topics themselves. The bulk of the template consisted of questions that practicing scientists ask themselves as they read an article, such as: "What is the overall purpose?"; "Do the methods appropriately address the question being asked?"; "Do the results support the conclusions?". The students brought their completed template and notes to class to discuss the paper in a small group and then with the class at large. They were allowed to make revisions following the discussion before submitting their template to be graded.

Coffee Chats were designed to encourage students to consider their learning in the class and articulate areas of confusion through private, digital conversations between the student and instructor. These casual, low-steak assignments built rapport with the instructor and fostered a safe environment for students to ask questions. Each week, students responded to a required set of prompts that typically included common areas of confusion and a reflection on their learning. These assignments were due before the chapter was covered in a lecture. A quick review of the responses provided insight into multiple students' misconceptions. The lecture content and discussions were then tailored for the cohort by highlighting these shared areas of confusion. Additionally, I responded to several prompts over the course of the semester to further foster conversation, build rapport, and encourage curiosity.

Leveraging student inquiry and fostering curiosity can provide additional support for students who entered Animal Behavior with lower GPAs or interest in the subject. Curiosity is a disposition that can be used as a proxy for lifelong learning and is suggested to be a pillar of academic performance (Fulcher, 2008; von Stumm et al., 2011). By nurturing intellectual curiosity, students can garner greater enjoyment from their studies than from intelligence and effort alone (von Stumm et al., 2011). This curriculum design provides the starting point for an approachable course while maintaining rigor and building critical thinking skills.

A potential consequence of opening an upper-level life science elective to non-life science majors is the disparity in preparation. Therefore, I aimed to determine if major or science background significantly impacted (1) academic success in Animal Behavior and (2) attitudes toward the course. If science background or major played a significant role in student academic success, then student grades, reflected in their final score, would differ, whereas students with more science preparation would earn higher scores because of their increased familiarity with the content. Predicting the response of attitudes towards the class is more complex. While some students may value the challenge of a difficult course, others may find it intimidating. As such, data were collected on attitudes towards the initiatives described above to leverage student experiences and their opinions on the content. This can provide feedback on student perceptions and fuel recommendations to increase student success in rigorous mixed-major electives.

Methods

Data Collection

In Fall 2021, 22 students were enrolled in Animal Behavior. This group consisted of Juniors and Seniors with majors in Biology, Human Services, and Psychology. Students were given a verbal and written explanation of the IRB-approved research and provided an informed consent form. As an incentive to participate, 15 extra credit points were awarded to those who joined the study. An alternative extra-credit assignment of equivalent effort worth 15 points was available for those who did not wish to participate. Students were informed that they could withdraw from the study at any time. Nineteen (N = 19) students agreed to participate in this research, consisting of biology (n=9) and psychology (n=10) majors.

The data collection consisted of three parts. (1) An onboarding survey where the students reported their major, academic year, grade point average (GPA; out of 4.0), and the number of science courses they completed before Fall 2021. (2) Two attitude surveys about how students felt about the course material, learning atmosphere, and student progress. These were delivered at midterm and after completing the final exam, but before final grades were posted. Surveys were not anonymous, but the students were informed that the responses were not reviewed until after final grades had been posted. (3) Graded work, including average exam score, average quiz score, and final scores.

All student data were downloaded and organized in an encrypted, password-protected Excel® spreadsheet saved to a password-protected hard drive. Each student was assigned a random number as an individual identifier with all data in the primary spreadsheet. All analyses were conducted on a de-identified copy of this spreadsheet, and the student order was rearranged to protect confidentiality and reduce the risk of bias.

Analysis

All analyses were conducted in R version 4.1.3, housed within R-Studio (R Core Team, 2021). The continuous variables were tested for normality using the Shapiro-Wilk test and homogeneity of variance via an F-test before continuing to analysis.

To determine the roles of major, preparation, and academic standing on the response variables of final score, exam averages, and quizzes, respectively, I ran three-way ANOVAs. The fixed effects were major, preparation, and standing. Major and standing each had two factors: biology/psychology and junior/senior, respectively. Preparation was divided into three factors according to the number of college science classes completed before Fall 2021. ‘Low preparation’ consisted of fewer than three courses, ‘moderate preparation’ consisted of 4-6 courses, and ‘high preparation’ consisted of 7-9 courses. It is important to note that psychology classes emphasizing the scientific method were included as science preparation (e.g., Research I & II).The results of the attitudes surveys delivered during midterms and finals were assessed using Mann-Whitney U tests to determine if there was a difference in student feelings between psychology and biology majors.

Results

Median GPA did not differ between biology (3.8) and psychology (3.5) majors; thus, it was not included in further analyses (Mann-Whitney test, U = 59, p = 0.28). All continuous variables—final score, exam averages, and quiz averages—were normally distributed with p-values > 0.05. A linear regression shows that GPA predicts the final grade in Animal Behavior ($r^2 = 0.71$, p << 0.001, Figure 3). All averages are reported ± SE.

Of the fixed-effects analyzed, major (f(1) = 5.69, p = 0.04) was the only predictor of final score, whereas preparation (f(2) = 0.57, p = 0.58) and standing (f(1) = 0.06, p = 0.81) played no role. A post hoc t-test showed that biology majors ($\bar{x}$ = 93.29 ± 1.61) earned significantly more points than their psychology major peers ($\bar{x}$ = 83.77 ± 2.88; t(18) = 2.80, p = 0.01, Figure 2) by the end of the semester. A similar trend followed for exam averages but not quiz averages. Major (f(1) = 5.5, p = 0.04) was the only predictor of exam averages, whereas preparation (f(2) = 0.49, p = 0.63) and standing (f(1) = 0.01, p = 0.94) played no role. A post hoc t-test showed that biology majors ($\bar{x}$ = 82.87 ± 2.12) averaged significantly higher than psychology majors in their exams ($\bar{x}$ = 66.19 ± 5.36; t(18) = 2.89, p = 0.01, Figure 2). Quiz averages were not explained by major(f(1) = 2.02, p = 0.18, Figure 2), preparation (f(2) = 0.47, p = 0.64), or standing (f(1) = 1.05, p = 0.33).

Student response scores tended to change between midterm (Table 1) and final surveys (Table 2). There was no statistical difference in median scores between biology and psychology majors at midterm (Table 1). At finals, students differed significantly in their responses by major for questions 3, 5, 6, 11, and 12 (Table 2, Figure 3). In most instances, students responded more favorably in the final survey, with a

Figure 2: Biology majors (n=9) scored significantly higher in final grades and exams than psychology majors (n=10). This trend is similar for quiz averages but is not statistically significant (N=19).

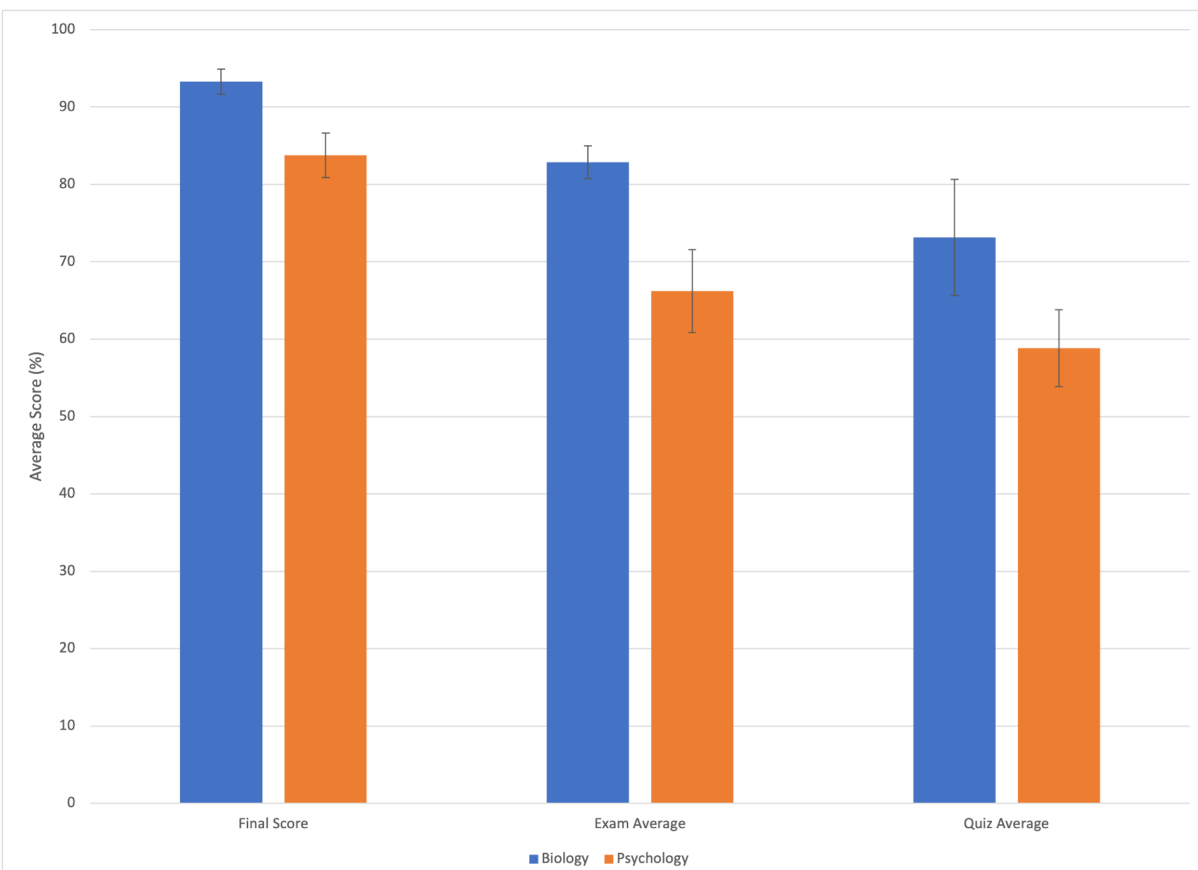


Table 1: Midterm responses for the attitude survey. Majors were similar in their responses to any question. These questions were scored on a 5-point Likert scale where 1 = Strongly disagree, and 5 = Strongly agree. The reported values are the percentage of students (N=19) who responded to each category.

Question	Question Text		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	*U*	*p-value*
Q1	I am comfortable in my learning environment.	*Biology*	26.32	0.00	5.26	5.26	10.53	*51*	*0.64*
		Psychology	10.53	15.79	15.79	5.26	5.26		
Q2	I learn something new each day.	*Biology*	26.32	5.26	0.00	5.26	10.53	*50.5*	*0.67*
		Psychology	15.79	21.05	0.00	10.53	5.26		
Q3	I am comfortable sharing my thoughts with my small group.	*Biology*	15.79	15.79	0.00	0.00	15.79	*46.5*	*0.93*
		Psychology	10.53	21.05	15.79	0.00	5.26		
Q4	I am comfortable sharing my thoughts with the group at large (e.g., the entire class).	*Biology*	21.05	5.26	10.53	5.26	5.26	*68*	*0.06*
		Psychology	0.00	15.79	0.00	26.32	10.53		
Q5	I am confident in my current scientific ability.	*Biology*	10.53	10.53	10.53	10.53	5.26	*59.5*	*0.24*
		Psychology	0.00	5.26	21.05	21.05	5.26		
Q6	I am doing well in this class.	*Biology*	15.79	5.26	15.79	5.26	5.26	*63*	*0.14*
		Psychology	0.00	5.26	26.32	10.53	10.53		
Q7	I enjoy the content of this class.	*Biology*	26.32	0.00	0.00	15.79	5.26	*53*	*0.52*
		Psychology	10.53	21.05	0.00	15.79	5.26		
Q8	I enjoy the organization of this class.	*Biology*	26.32	5.26	0.00	10.53	5.26	*54.5*	*0.45*
		Psychology	10.53	21.05	10.53	5.26	5.26		
Q9	I find the coffee chats helpful.	*Biology*	21.05	5.26	0.00	10.53	10.53	*42.5*	*0.87*
		Psychology	15.79	15.79	5.26	15.79	0.00		
Q10	I find the group activities helpful.	*Biology*	26.32	5.26	0.00	0.00	15.79	*48.5*	*0.79*
		Psychology	15.79	26.32	0.00	5.26	5.26		
Q11	The Scientific Literacy assignments are improving my understanding of science.	*Biology*	21.05	10.53	0.00	5.26	10.53	*54*	*0.47*
		Psychology	5.26	26.32	5.26	10.53	5.26		
Q12	Since the class began, I have grown in my scientific understanding.	*Biology*	21.05	10.53	0.00	5.26	10.53	*54.5*	*0.45*
		Psychology	10.53	10.53	15.79	5.26	10.53		

few exceptions (Table 3). Biology students tended to report a lower level of comfort with sharing in large groups, while psychology students tended to increase their comfort in these discussions from midterms to finals. However, psychology students split their preferences for small group discussions, enjoying class content and group activities. Here, some students tended to report more favorably, while others tended to vote less favorably.

Discussion

These preliminary data indicate that major plays a significant role in a student's academic success in and attitudes towards Animal Behavior when it is delivered as a mixed-cohort upper-level course. Although biology major GPA was numerically higher than psychology majors, the difference was not significant. Psychology majors clustered in two groups where roughly half the class had a GPA greater than 3.6 and half had a GPA below 3.3. Most biology majors cluster with the

Table 2: Final responses for attitude survey. Majors differed significantly in several questions (signified by bolded p-values). These questions were scored on a 5-point Likert scale, where 1 = Strongly disagree, and 5 = Strongly agree. The reported values are the percentage of students (N=19) who responded to each category.

Question	**Question Text**		**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly Disagree**	***U***	***p-value***
Q1	I am comfortable in my learning environment.	*Biology*	26.32	10.53	5.26	5.26	0.00	*62.5*	*0.15*
		Psychology	10.53	21.05	5.26	10.53	5.26		
Q2	I learn something new each day.	*Biology*	36.84	5.26	0.00	5.26	0.00	*66.5*	*0.06*
		Psychology	15.79	21.05	0.00	10.53	5.26		
Q3	I am comfortable sharing my thoughts with my small group.	*Biology*	42.11	0.00	0.00	0.00	5.26	*68.5*	***0.04***
		Psychology	15.79	21.05	0.00	10.53	5.26		
Q4	I am comfortable sharing my thoughts with the group at large (e.g., the entire class).	*Biology*	15.79	10.53	5.26	10.53	5.26	*54.5*	*0.45*
		Psychology	10.53	5.26	15.79	10.53	10.53		
Q5	I am confident in my current scientific ability.	*Biology*	21.05	15.79	5.26	5.26	0.00	*73.5*	***0.02***
		Psychology	0.00	10.53	31.58	5.26	5.26		
Q6	I am doing well in this class.	*Biology*	26.32	10.53	5.26	5.26	0.00	*71.5*	***0.03***
		Psychology	0.00	26.32	10.53	5.26	10.53		
Q7	I enjoy the content of this class.	*Biology*	31.58	5.26	5.26	5.26	0.00	*62.5*	*0.14*
		Psychology	15.79	15.79	5.26	5.26	10.53		
Q8	I enjoy the organization of this class.	*Biology*	36.84	5.26	0.00	5.26	0.00	*66*	*0.07*
		Psychology	15.79	21.05	5.26	5.26	5.26		
Q9	I find the coffee chats helpful.	*Biology*	26.32	10.53	5.26	5.26	0.00	*62*	*0.16*
		Psychology	10.53	21.05	5.26	15.79	0.00		
Q10	I find the group activities helpful.	*Biology*	31.58	10.53	0.00	0.00	5.26	*57*	*0.30*
		Psychology	21.05	21.05	0.00	0.00	10.53		
Q11	The Scientific Literacy assignments are improving my understanding of science.	*Biology*	26.32	15.79	0.00	0.00	5.26	*68.5*	***0.05***
		Psychology	5.26	21.05	15.79	10.53	0.00		
Q12	Since the class began, I have grown in my scientific understanding.	*Biology*	42.11	0.00	0.00	5.26	0.00	*69.5*	***0.03***
		Psychology	15.79	15.79	10.53	5.26	5.26		

psychology majors with GPAs above 3.6, with one outlier in the second psychology cluster (Figure 3). This observed clustering of the data likely drove the numerical, yet non-significant, difference in GPA between the majors. Unsurprisingly, GPA is related to final score, as found elsewhere (Bazelais et al., 2016).

Psychology students consistently scored at least 1.5 letter grades lower on content-heavy assessments than biology students. Two psychology students earned scores equivalent to their reported GPA, but the remaining eight earned scores in the mid-80s or below (Figure 3). A recent study by Tomkin and West (2022) suggests that observed GPA is a misleading measure of academic performance when comparing science, technology, engineering, and mathematics (STEM) students with non-STEM students. Researchers examined the grades of 64,860 students (STEM vs non-STEM; n = 35,034 vs n = 39,826) over 10 years (2006 to 2015 inclusive) to evaluate inter-course grading disparities and assess GPA models. Their results show that STEM majors are graded more stringently than non-STEM majors. STEM students had greater academic success than their non-STEM peers even though their observed GPAs were similar. However, heterogeneity among STEM disciplines was also present, where engineering students' GPAs were depressed more compared with biology students' GPAs. The authors reported that biology and psychology student GPAs show different inflation levels, but it is unclear whether the difference between them is significant. Tomkin and West encourage using a weighted logistic model of GPA when comparing student performance. This could provide a truer sense of prior academic performance and account for prior grade disparities between the majors. While this is outside the scope of the current project, futurereplications of this research would benefit by including this model.

The primary hypothesis of this study defined academic success as the final score. However, if we were to define success as passing the course (earning 70% or higher), then we reach a different conclusion. An exploratory post hoc X^2 test showed no difference in passing the class between the majors ($X^2(1,19) = 0.95$, $p = 0.33$, Figure 4). However, there was a significant difference between the majors for passing exams ($X^2(1,19) = 9.98$, $p = 0.002$) and quizzes ($X^2(1,19) = 9.02$, $p = 0.003$; Figure 4), suggesting that students were

Figure 3: GPA is predictive of the final score.

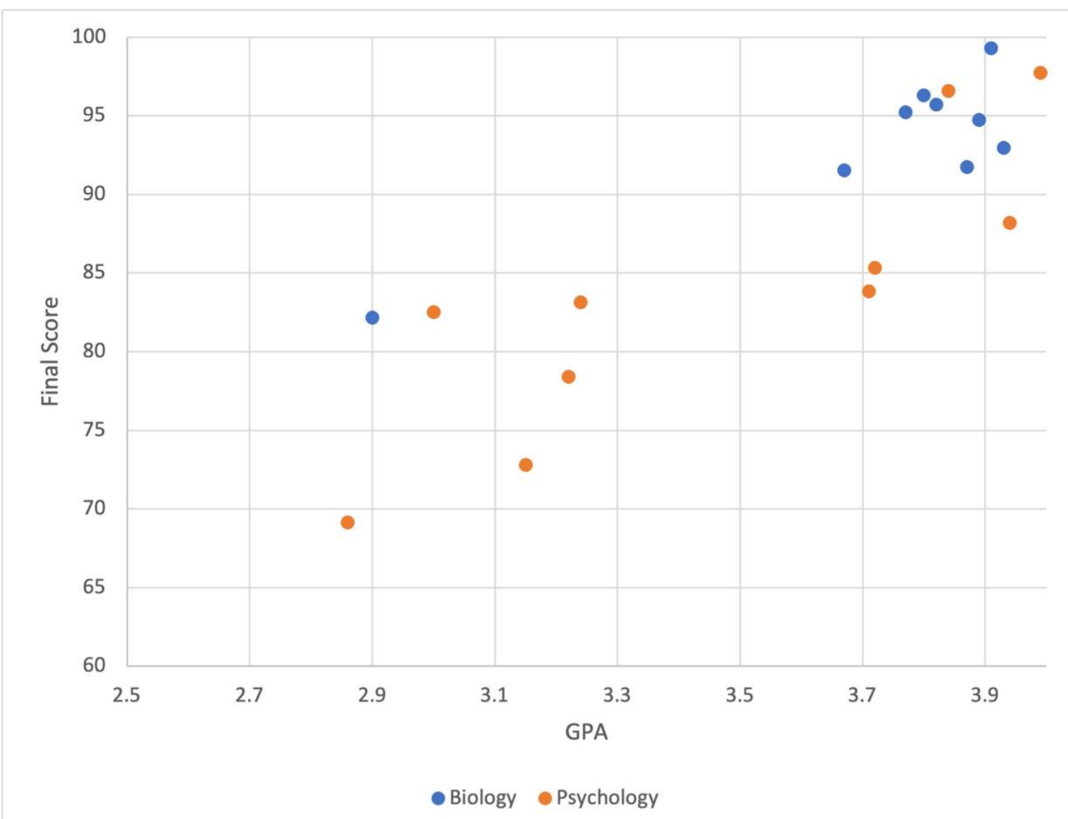
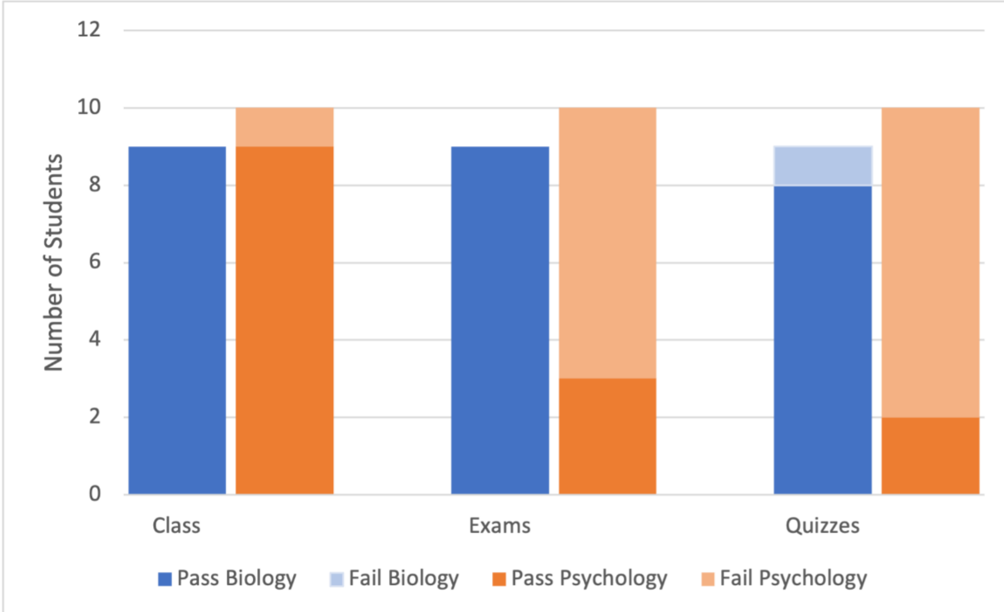


Figure 4: Measuring class success by pass (≥70%) fail (<70%; N=19).



raising their final grades through the other assignments. Mixed assessment methods have been shown to reduce the performance gap, making courses more equitable (Cotner and Ballen, 2017). Content-heavy, high-stakes exams and quizzes made up the bulk of the final grade in Animal Behavior, but it is evident that the low-stakes assessments bolstered these grades. Future sections of this course would benefit from revisiting the syllabus to consider other ways of distributing points, with more low-stakes assignments targeted at content knowledge. In addition to providing opportunities to practice with this content before attempting high-stakes assessments, the redistribution of points may make the course more accessible for all.

Although psychology students consistently scored lower, they reported feeling they were doing well in the class. Attitudes toward the class were only significantly different for the final exam survey. These differences were likely driven by the greater magnitudes of change where biology students swung from 'strongly disagree' to 'agree' or 'strongly agree' (Table 3). Biology students tended to score more strongly and positively than psychology students, whose responses were more distributed across the options. However, we see a positive trend for psychology students feeling more comfortable in class and their scientific ability.

One factor leading to feeling more comfortable in the class could be changes in the module focus. The early modules of Animal Behavior focus on the proximal mechanisms of behavior, including genetics and physiology, which lays the foundation for other modules. These mechanisms build upon concepts that all students have seen in either Introduction to Psychology or Introduction to Biology I/II. However, biology students and those interested in physiological psychology likely entered Animal Behavior with a stronger understanding of these mechanisms. At the same time, the rest of the students had not seen these topics since early in their academic careers. The modules covered after the midterm were likely more familiar to psychology students because they explored concepts like learning, social dynamics, and parental care. I would recommend adding pre-class review assignments or games specifically for the proximal mechanism modules. This can inform all students of the depth of understanding I'm expecting as we start discussing these concepts and remind them that they have seen these topics before.

Another factor leading to increased comfort over time in Animal Behavior could be attributed to increased camaraderie among discussion group members. This study was conducted when COVID-19 safety measures were in place; thus, discussion groups were determined according to where the students sat and remained consistent throughout the semester. While this allowed for a small level of self-selection due to sitting with peers, sometimes peer groups were split because of how the rows were divided. This led to groups with heterogeneous backgrounds, some of which were composed of mostly one major and one or two students of a different major. As the students

Table 3: Difference in responses between midterm and final attitude surveys. Positive changes are highlighted with bold text, while negative changes are highlighted with italicized text. Questions with a significant difference in major responses are bolded with an asterisk *.

Question	Question Text		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
Q1	I am comfortable in my learning environment.	*Biology*	0	**10.53**	0	0	*-10.53*
		Psychology	0	**5.26**	*-10.53*	**5.26**	0
Q2	I learn something new each day.	*Biology*	**10.53**	0	0	0	*-10.53*
		Psychology	0	0	0	0	0
Q3*	**I am comfortable sharing my thoughts with my small group.**	*Biology*	**26.32**	*-15.79*	0	0	*-10.53*
		Psychology	**5.26**	0	*-15.79*	**10.53**	0
Q4	I am comfortable sharing my thoughts with the group at large (e.g., the entire class).	*Biology*	*-5.26*	**5.26**	*-5.26*	**5.26**	0
		Psychology	**10.53**	*-10.5*	**15.79**	*-15.79*	0
Q5*	**I am confident in my current scientific ability.**	*Biology*	**10.53**	**5.26**	*-5.26*	*-5.26*	*-5.26*
		Psychology	0	**5.26**	**10.53**	*-15.79*	0
Q6*	**I am doing well in this class.**	*Biology*	**10.53**	**5.26**	*-10.53*	0	*-5.26*
		Psychology	0	**21.05**	*-15.79*	*-5.26*	0
Q7	I enjoy the content of this class.	*Biology*	**5.26**	**5.26**	**5.26**	*-10.53*	*-5.26*
		Psychology	**5.26**	*-5.26*	**5.26**	*-10.53*	**5.26**
Q8	**I enjoy the organization of this class.**	*Biology*	**10.53**	0	0	*-5.26*	*-5.26*
		Psychology	**5.26**	0	*-5.26*	0	0
Q9	I find the coffee chats helpful.	*Biology*	**5.26**	**5.26**	**5.26**	*-5.26*	*-10.53*
		Psychology	*-5.26*	**5.26**	0	0	0
Q10	I find the group activities helpful.	*Biology*	**5.26**	**5.26**	0	0	*-10.53*
		Psychology	**5.26**	*-5.26*	0	*-5.26*	**5.26**
Q11	The Scientific Literacy assignments are improving my understanding of science.	*Biology*	**5.26**	**5.26**	0	*-5.26*	*-5.26*
		Psychology	0	*-5.26*	**10.53**	0	*-5.26*
Q12*	**Since the class began, I have grown in my scientific understanding.**	*Biology*	**21.05**	*-10.53*	0	0	*-10.53*
		Psychology	**5.26**	**5.26**	*-5.26*	0	*-5.26*

moved through the content with their discussion group members, they may have increased their confidence in their understanding of the topics and their trust in each other. In future course iterations, I recommend assigning students to discussion groups. This will ensure that various backgrounds and voices contribute to the discussion in the small group setting and could reduce the likelihood of being the only member of a particular major.

While illuminating, this study has limitations. These data are from one semester of students with various levels of interest in animal behavior. Although there is an even distribution of students between biology and psychology majors, the sample size is still small (N = 19). Furthermore, because of the campus' size, there were limited upper-level courses that students could enroll in, resulting in some students taking Animal Behavior as a last resort. Several psychology students disclosed to me after the course was complete that they enrolled in Animal Behavior because it was the only upper-level that fit their schedule. While this would have been an interesting layer to add to the analysis, the surveys did not include 'interest in animal behavior'. A larger sample size across multiple years with survey questions relating to interest in animal behavior would likely provide more robust data to draw conclusions.

Conclusions

Overall, these data suggest that a student-centered upper-level elective emphasizing critical thinking and transferrable skills can be successful. Still, changes to the syllabus to redistribute points toward lower-stakes assignments should be considered to improve equitability and student comfort early in the semester. Future iterations of this research should consider a weighted logistic model of GPA to account for prior grading disparities and have a truer sense of prior academic performance.

Acknowledgments

This study was approved under the IRB number SF092021LWCIRB.

References

Bazelais, P., Lemay, D.J., & Doleck, T. (2016). How does grit impact college students' academic achievement in science? European Journal of Science and Mathematics Education, 4(1), 33-43.

Biwer, F., Oude Egbrink, M.G.A., Aalten, P., & D.E. Bruin, A.B.H. (2020). Fostering effective learning strategies in higher education – A mixed-methods study. Journal of Applied Research in Memory and Cognition, 9(2), 186–203. https://doi:10.1016/j.jarmac.2020.03.004

Cotner, S. & Ballen, C.J. (2017). Can mixed assessment methods make biology classes more equitable? PLOS ONE, 12(12), e0189610. https://doi.org/10.1371/journal.pone.0189610

Fulcher, K.H. 2008. Curiosity: A link to assessing lifelong learning. Assessment Update: Progress, Trends, and Practices in Higher Education, 20(2), 5–7.

Millea, M., Wills, R., Elder, A., & Molina, D. (2016). What matters in college student success? Determinants of college retention and graduation rates. Education, 138(4), 309 –322.

R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Accessed from https://www.R-project.org/

Richmond, A.S., Slattery, J.M., Mitchell, N., Morgan, R.K., & Becknell, J. (2016). Can a learner-centered syllabus change students' perceptions of student–professor rapport and master teacher behaviors? Scholarship of Teaching and Learning in Psychology, 2(3), 159–168. https://doi:10.1037/stl0000066

Schouten, G. (2017). On meeting students where they are: Teacher judgment and the use of data in higher education. Theory and Research in Education, 15(3), 321–338. https://doi:10.1177/1477878517734452

Sly, L. (1999). Practice tests as formative assessment improve student performance on computer-managed learning assessments. Assessment & Evaluation in Higher Education, 24(3), 339–343. https://doi:10.1080/0260293990240307

Tomkin, J.H. & West, M. (2022). STEM courses are harder: Evaluating inter-course grading disparities with a calibrated GPB model. International Journal of STEM Education, 9(27), 1-17. https://doi.org/10.1186/s40594-022-00343-1

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The hungry mind: Intellectual curiosity is the third pillar of academic performance. Perspectives on Psychological Science, 6(6), 574–588. https://doi:10.1177/1745691611421204

Leveraging an upper-level microbiology CURE to advance scientific communication skills

Ebenezer Korkor[a]* and Rebekka Darner[ab]

[a] *Center for Mathematics, Science, & Technology, Illinois State University, Normal, IL, 61790-5960 USA;* [b] *School of Biological Sciences, Illinois State University, Normal, IL, 61790-4120 USA*

CONTACT *Ebenezer Korkor, ekorkor@ilstu.edu, Center for Mathematics, Science, & Technology, Illinois State University, Normal, Illinois, 61790-4120, USA

ABSTRACT

Course-based undergraduate experiences (CUREs) have been employed to enhance students' content knowledge, self-efficacy, science identity, and enrollment in postgraduate programs. In this study, we used it as a science communication skills enhancement tool. The CURE-Comm Framework was implemented to integrate science communication into a CURE in an upper-level microbiology course. The results showed significant improvement in students' ability to communicate scientific information to diverse audiences, research comprehension, ethics, and practical skills. Pre/post-course surveys indicated no significant increase in communication skills toward non-science audiences, researcher identity, confidence and independence, and equity, diversity, and inclusion awareness. However, analysis of in-class and podcast presentations and interviews revealed important gains in all areas. This study highlights the utility of the CURE-Comm Framework in enhancing science communication skills, particularly through data analysis, literature exposure, multiple writing and oral presentation opportunities, and constructive feedback.

Keywords: SciComm, science communication, undergraduate research experiences

INTRODUCTION

Higher education institutions have increasingly adopted course-based undergraduate research experiences (CUREs) to provide students with hands-on, real-world research opportunities integrated into their coursework, enhancing their academic engagement, and learning outcomes (Wei & Woodin, 2011; Bangera & Brownell, 2014). It is a cost-effective way to implement the recommendation of the National Science Research Council (2013) and the American Association for the Advancement of Science (2011) to provide high-quality research experiences for students (Seymour et al., 2004). Amidst the variation in content, duration, and implementation strategies of different CUREs (Dolan 2016), every CURE is characterized by five core features: (1) engaging in science practices, (2) discovery, (3) broadly important work, (4) collaboration, and (5) iteration (Auchincloss et al., 2014). CUREs enhance content knowledge and academic performance (Shaffer et al., 2014, Ing et. Al., 2021), persistence in STEM, scientific self-efficacy, scientific identity, and scientific thinking (Brownell et al., 2015). They also improve students' data analysis and interpretation skills (Shaffer et al., 2014). Not surprisingly, increased science communication (SciComm) skills have also been suggested as a major derivative of CUREs (Auchincloss et al., 2017; Corwin et al., 2015).

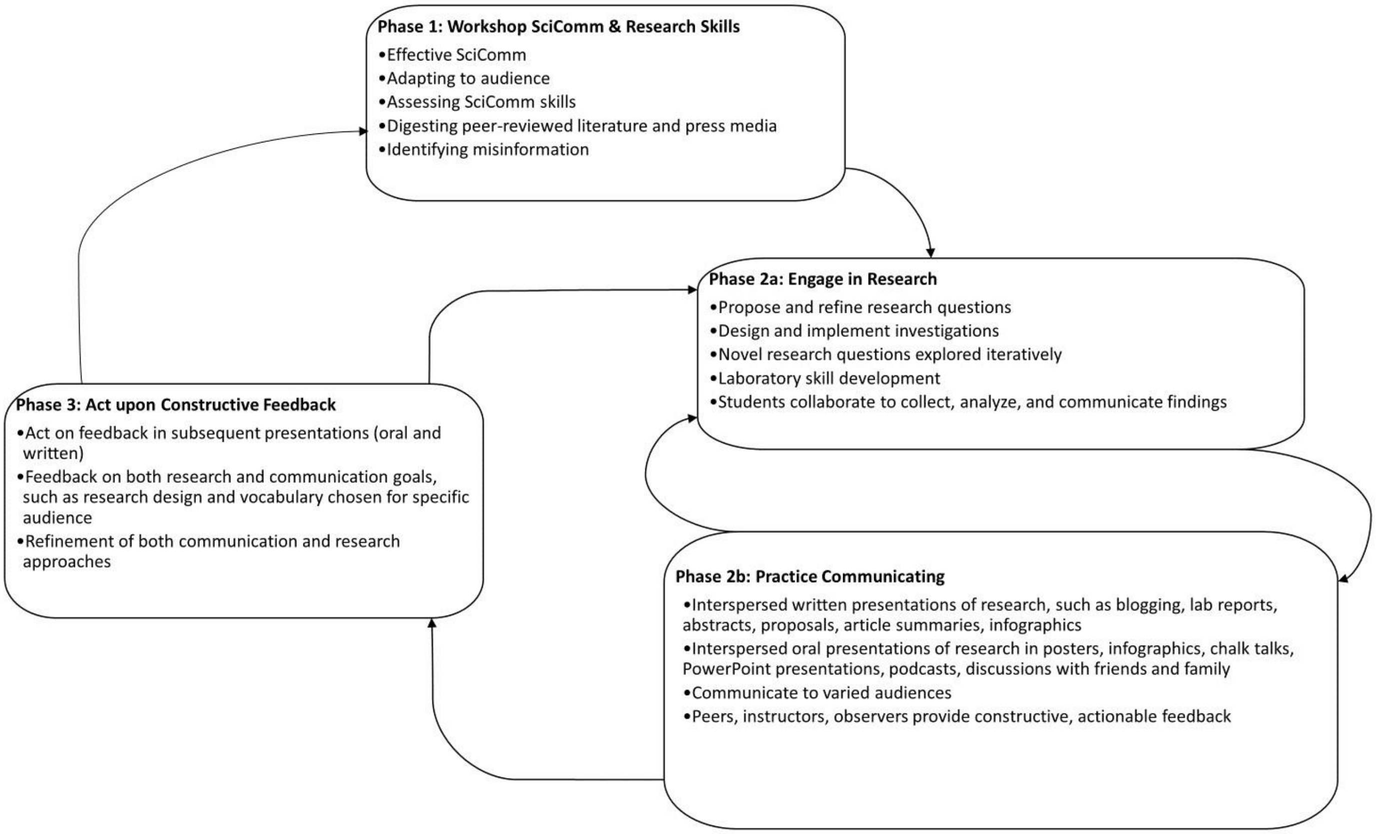
Conceptual Framework

The CURE-Comm Framework was developed through a comparison of instructional strategies used to teach SciComm skills and in the context of CUREs (Authors, in press). In this comparison, we discovered an underutilization of pedagogies that foster SciComm skills during the implementation of CUREs. Hence, the CURE-Comm Framework provides a guide for harnessing the power of CUREs to develop SciComm skills. The CURE-Comm Framework (Figure 1) serves as the foundation for this study. The framework proposes an iterative cycle involving workshopping both SciComm and research skills, engagement in research, getting practice communicating both orally and in writing, and receiving and acting upon constructive feedback. Its effectiveness rests upon the frequency of iterations (Authors, in press), so students should cycle through these steps at least three times throughout the term, adapting to different audiences (e.g., scientist vs. layperson) and modalities (e.g., written vs. oral).

Research Questions

The primary objective of this study was to examine the utilization of the CURE-Comm Framework for enhancing science communication skills without sacrificing the primary purposes of CUREs. Elements of

Fig. 1. The CURE-Comm Framework, a model for infusing development of SciComm into CUREs.



the CURE-Comm Framework were integrated into an upper-level applied microbiology course in a Midwestern university for two consecutive years. This course is a CURE that is part of the Small World Initiative (2024), the goal for which is to increase the pool of antibiotics to counteract the emerging antibiotic resistance crises. This course engages students in research to identify microorganisms from soil samples that produce antimicrobial compounds. This study investigated two research questions: (1) To what extent does the course meet the goals of a CURE informed by the CURE-Comm Framework, including fostering research confidence, science identity, researcher ethics, equity and inclusion, research comprehension and communication, practical research skills, and self-efficacy related to doing research? (2) To what extent do the instructional methods implemented in the CURE under study foster SciComm skills? We sought to develop grounded hypotheses about how this CURE fostered SciComm skills.

Methods

Research Setting

This study occurred at a large R2 Midwestern institution. The 4-credit course helps students recognize the impact of microbes on society, apply the process of inquiry to solve novel problems, and communicate scientific content verbally and in writing. The course is available to students in a biological science's academic unit, meets twice per week for 6 hours, and alternates between laboratory and lecture sessions. A seminar-style biological experimentation course and an introductory microbiology course were the prerequisites, which some students took online due to the COVID-19 pandemic and thus entered the course with fewer laboratory skills than expected. The instructor used the first two meetings to construct students' fundamental knowledge of microbiology and basic laboratory techniques needed for successful project completion.

To date, the CURE has been offered three times. Nine and 8 students registered for the course in the Fall of 2021 and Fall of 2022, respectively. The course is open to graduate and undergraduate biology majors, although undergraduate students (n = 5) are the focus of this study. The small class size permits frequent faculty-to-student interaction and mentoring and made the workload manageable for the instructor who taught the course without a teaching or research assistant. These small class sizes impact the sample size for this study, leading us to employ methodologies that do not rely heavily on large sample sizes.

Reviewing primary literature is incorporated into the course to help students learn more about the theory and techniques researchers have successfully used to isolate and characterize bacteria from the soil. Students identify a gap in the literature reviewed, design a project, and prepare a proposal based on that and present it to the class. These proposals serve as the foundation for engaging in Phase 2 of the CURE-Comm Framework (Figure 1). Students made three research presentations, with the second and third informed by oral and written feedback from the previous one. Constructive feedback was from fellow students, the instructor, and an independent observer (the first author). The atmosphere during each presentation was relaxed, allowing students to freely ask questions to clarify concepts, offer constructive criticism, and review presentation materials and styles.

In this CURE, students were all limited to working around a general research question: How can we find new antibiotics? Guided by this central question, students working in pairs designed their research projects, collected soil samples independently, and brought them to the lab for identification and metabolic characterization. Though students worked in pairs, each student was required to collect individual soil samples and successfully characterize at least one novel antibiotic-producing bacterium using molecular and biotechnology techniques. Aside from these constraints, students had autonomy over their research decisions and discovered a novel antibiotic-producing organism(s). Students' projects were independent of the instructor's research program, but with rich expertise in microbiology research, the researcher offered quality mentoring and support.

Finally, students shared their experiences in the CURE and research findings with a non-science audience when interviewed for a local podcast that highlights research on campus. The podcast interview was conducted by one of the podcast producers and the first author.

Research Design

Participants of this study were students enrolled in the above CURE course. A total of 5 undergraduate students participated in the study, with one student agreeing to be interviewed. This mixed-methods study employed an explanatory sequential design in which quantitative data was collected first, followed by qualitative data collection provide insight and explanation about why quantitatively measured changes were observed (Creswell, 2015). We administered pre- and post-course surveys using the Entering Research and Learning Assessment instrument (ERLA, Butz & Branchaw, 2020) to measure students gains in research comprehension and communication skills, practical research skills, research ethics, researcher identity, and equity and inclusion awareness. ERLA items ask students to self-report their skill level on a variety of tasks using a five-point Likert scale (1 = no skill, 5 = high skilled). Due to the ranked nature of the data and small sample sizes, pre-course and post-course levels of students' researcher confidence and independence, science research identity, experimental research skills confidence, science audience communication skills, and non-science audience communication skills were compared using Wilcoxon signed-ranked tests. Cohen's (1992) significance of product moment r, which indicates effect size as small ($r \simeq 0.1$), medium ($r \simeq 0.3$), and large ($r \geq 0.5$), were used.

Due to participants limited previous research experience, students' changes in research ethics and identity, equity, diversity and inclusion, research comprehension, and practical research skills were only assessed on the post-course administration and were analyzed with a one-sample Wilcoxon signed-rank test. Data gathered from administration of the ERLA were used to address the first research question.

The first author conducted in-class observations of students' research presentations to provide data regarding student's SciComm skill development, specifically toward a scientific audience. During observations, each student's science communication skills were measured using the Sevian and Gonsalves (2008) rubric. At each presentation throughout the CURE, a student could have received a score of 1-4 across 10 components addressed by the rubric (Sevian & Gonsalves, 2008). A repeated measures analysis of variance (RM-ANOVA) was performed on each participant's rubric scores from their three research presentations throughout the CURE, and partial eta-squared (η^2) was calculated to estimate effect size. In cases when significance was detected, paired t-tests were performed to detect the source of significance. For each student, a comparison was made between presentations 1 and 2, 2 and 3, and then 1 and 3. Hence an adjusted α-value of 0.017 (0.05/3) was used.

A one-time observation of in-class presentations was conducted in a microbiology course (N=50) as a comparison group. This microbiology course has traditional laboratory activities and similar prerequisites to the CURE under study. These students' science audience communication skills were scored with the Sevian and Gonsalves (2008) rubric and compared to the CURE's students' science audience SciComm skills using a two-sample t-test assuming equal variances. A preliminary test for the equality of variances indicated that the variances of the two groups (CURE presentation 3 and comparison group presentation) were not significantly different ($F(4, 49) = 0.652$, $p = 0.371$). Podcast interviews were also scored by the first author using a Sevian and Gonsalves (2008) rubric, augmented with two items from Murdock's (2017) rubric for SciComm skills, to capture students' science communication with a non-science audience. This data was used to address the second research question.

Lastly, one participant, Evason (pseudonym for Student 1) was interviewed post-course to provide a detailed account to inform the development of grounded hypotheses about how the course fostered research and SciComm skills. Evason was a senior year molecular and cellular biology (MCB) major. According to Evason, her selection of MCB as her major was influenced by her high school anatomy and physiology teacher, whose instruction sparked her interest in the field. Evason had some wet-lab and traditional course-related lab experiences, but this CURE was her first course-based authentic research experience. Comparatively, Evason felt that this class was very research intensive and unique because it offered the opportunity to design and conduct their own research. The interview of Evason was semi-structured interview, allowing for follow-up questions following a set of predetermined questions to guide the conversation (Merriam, 2009), and it was used to address both research questions. Thematic analysis was used to analyze interview data (Clarke & Braun, 2016). The interview was first transcribed and open-coded; open codes were combined into fewer, more comprehensive themes. Emergent themes from analysis of student interview were research confidence, research comprehension, career aspirations, communication about research, communication to non-scientists.

Results

Research Question 1

Using the ERLA survey instrument, data on students' research skills were gathered pre- and post-course and analyzed using a Wilcoxon signed-ranked test (Figure 2). Students' research confidence and independence indicated no significant difference before (Mdn = 34, n=5) and after (Mdn = 33, n=5) the CURE ($Z = -0.135$, $p = .892$, $r = 0.06$). Similarly**,** no significant change was observed in student's research identity before (Mdn = 16, n = 5) and after (Mdn = 20, n= 5) the course ($Z = -0.406$, $p = .684$, $r = 0.201$). Students' confidence in sharing their research to a science audience significantly increased between before the CURE (Mdn = 58, n= 5) and after (Mdn= 68, n=5) the course ($Z = -1.841$, $p = .066$, $r = 0.822$). Students reported having significantly higher experimental research skill confidence after the intervention (Mdn = 51, n= 5) than before (Mdn = 47, n=5) the course ($Z = -2.023$, $p = 0.043$, r = 0.9)51.

Items that were only measured on the post-course survey were analyzed using a one sample Wilcoxon signed-rank test, in which the observed median of each item was compared with a hypothetical median to see if students' scores were significantly higher than average. Regarding students' research ethics and identity skills, the sample median (Mdn= 12) was significantly higher than the hypothesized population median (Mdn = 5) ($Z = 2.041$, $p = 0.041$, $r = 0.913$). Regarding equity, diversity, and inclusion students' self-reported understandings (Mdn = 19) were not significantly different from the theoretical median (Mdn = 8), ($Z = 1.625$, $p = 0.104$, $r = 0.728$). Students' research comprehension and communication skills (Mdn= 36) were significantly greater than the theoretical median (Mdn = 20) ($Z= 2.032$, $p = 0.042$, $r = 0.909$). Regarding practical research skills, the theoretical median (Mdn = 15) was significantly lower than the observed median (Mdn = 30) ($Z = 2.023$, $p = 0.043$, $r = 0.905$).

Fig. 2. Student gains in objectives related to both research and SciComm skills across the CURE. Significant improvements were observed in confidence related to experimental research.

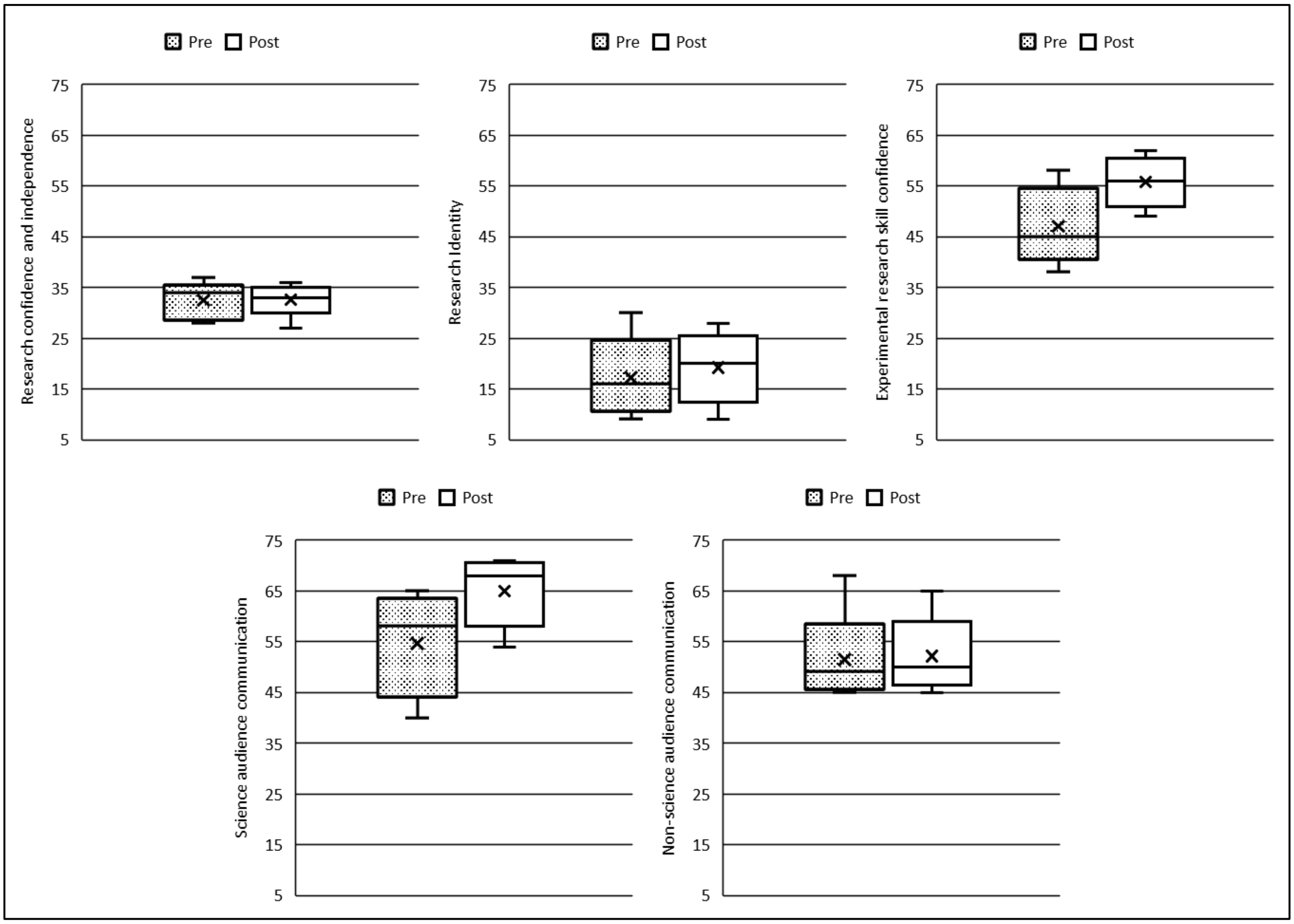


Table 1. Means and standard deviations for students' 3 research presentations and omnibus RM-ANOVA results.

Student	Mean + SD			F (2,9)	p-value	η^2
	Talk 1	Talk 2	Talk 3			
1	2.60 + 0.70	2.80 + 0.63	3.50 + 0.53	5.86	0.011*	0.59
2	2.90 + 0.32	3.00 + 0.47	3.30 + 0.48	2.67	0.111	-
3	2.80 + 0.63	3.30 + 0.48	3.70 + 0.48	36.0	<0.001*	0.90
4	2.40 + 0.70	3.40 + 0.52	3.80 + 0.42	17.8	<0.001*	0.82
5	2.30 + 0.48	3.30 + 0.48	4.00 + 0.32	44.6	<0.001*	0.92

Research Question 2

The pre/post questionnaire composed of the ERLA was augmented with items related specifically to participants' confidence in communicating with non-science audiences, which indicated no change before (Mdn = 49, n=5) and after (Mdn = 50, n=5) the CURE (Z = -0.680, p= .496, r = 0.301; Figure 2).

Data collected through observations of student's three in-class research were scored using the Sevian and Gonsalves (2008) rubric for measuring the effectiveness of scientific explanations and analyzed using RM-ANOVA on each participant's rubric scores. Statistical significance was detected by the omnibus RM-ANOVAs among Student 1, Student 3, Student 4, and Student 5's rubric scores, while Student 2 did not experience significant change (Table 1).

Table 2. Pairwise comparisons of student's three in-class presentations using paired t-tests at (adjusted α = 0.017). Asterisks indicate statistical significance.

Student	Comparison of Presentations (t-statistic, p-value)			
		1	2	3
1	1	-	2.92, 0.509	2.92, 0.018
	2	2.92, 0.509	-	2.92, 0.193
	3	2.92, 0.018	2.92, 0.193	-
2	1	-	2.92, 0.591	2.92, 0.037
	2	2.92, 0.591	-	2.92, 0.193
	3	2.92 0.037	2.92, 0.193	-
3	1	-	3.003, 0.013*	2.92, <0.001*
	2	3.003, 0.013*	-	2.92 0.037
	3	2.92, <0.001*	2.92 0.037	-
4	1	-	2.92, 0.004*	2.92, <0.001*
	2	2.92, 0.004*	-	2.92, 0.104
	3	2.92, <0.001*	2.92, 0.104	-
5	1	-	2.92, 0.001*	3.003, <0.001*
	2	2.92, 0.001*	-	2.92, 0.005*
	3	3.003, <0.001*	2.92, 0.005*	-

Table 3. Students' non-science audience communication scores across aspects of scientific communication. Italicized features are from the Murdock (2017) rubric, while all others arise from the Sevian and Gonsalves (2008) rubric.

Student	Structure & balance: Relevance & importance	Engagement or response to audience	Clear choice of language	Explain science process	Factual knowledge	How knowledge is understood	*Ability to transfer knowledge to broader context*	*Trustworthy and personable*
1	2	4	3	3	3	3	4	3
2	4	4	4	3	3	3	4	3
3	3	4	4	3	3	3	4	3
4	4	4	4	4	4	4	4	3
5	4	4	4	4	4	3	4	3
Mean	3.4	4	3.8	3.6	3.4	3.4	4	3.2

Pairwise comparisons of SciComm skills across presentations (Table 2, Figure 3) revealed that student 1 improved between presentation 2 and 3 but students 3, and 4 significantly improved between presentations 1 and 3. Student 2 had no change in SciComm skills whilst student 5 experienced significant improvement at each presentation.

A t-test comparison showed that students in the CURE initially scored lower ($M = 26$, $SD = 1.14$, $N = 5$) than the comparison group ($M = 30.58$, $SD = 2.98$, $N = 50$) in SciComm skills. However, by the final presentation, CURE students performed significantly better than the comparison group ($M = 36.4$ vs $M = 30.58$), with $t(53) = -3.31$, $p < 0.002$ and $t(53) = 4.215$, $p < .001$, respectively.

The podcast interview was analyzed using a combined rubric adapted from Sevian and Gonsalves (2008) and Murdock (2012) to assess science communication skills to a non-technical audience. Students showed strong SciComm skills for non-science audiences (Table 3). While most aspects of communication saw moderate to high gains (Table 4), students struggled with scaffolding explanations, mental images, and media use, likely due to podcast format limitations.

Emergent Hypotheses

Evason (pseudonym) was interviewed following the CURE to inform the development of grounded hypotheses about how the course fostered research and SciComm skills. Emergent themes from analysis of student interview were research confidence, communication about research, communication with non-scientists, and career aspirations (Figure 4).

Fig. 3. Changes in students' SciComm skills over the course of the CURE. SciComm scores were assigned using the Sevian and Gonsalves (2008) rubric, could range 10-40, and were scored by the first author. Pairwise comparisons conducted between early, mid, and late presentation scores revealed that students 1(■), 3(▲), and 4(●) significantly improved between presentations 1 and 3, while student 2(×) had no change in SciComm skills. Student 5(♦) experienced significant improvement at each presentation.

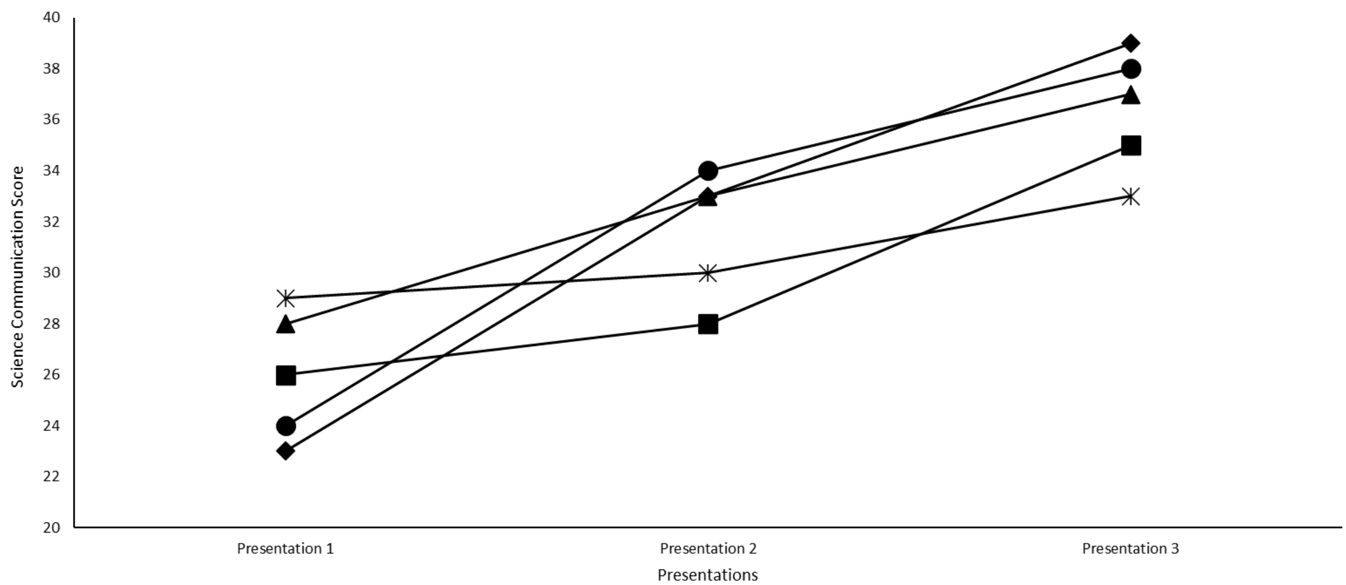


Table 3. Students' non-science audience communication scores across aspects of scientific communication. Italicized features are from the Murdock (2017) rubric, while all others arise from the Sevian and Gonsalves (2008) rubric.

Student	**Structure & balance: Relevance & importance**	**Engagement or response to audience**	**Clear choice of language**	**Explain science process**	**Factual knowledge**	**How knowledge is understood**	***Ability to transfer knowledge to broader context***	***Trustworthy and personable***
1	2	4	3	3	3	3	4	3
2	4	4	4	3	3	3	4	3
3	3	4	4	3	3	3	4	3
4	4	4	4	4	4	4	4	3
5	4	4	4	4	4	3	4	3
Mean	3.4	4	3.8	3.6	3.4	3.4	4	3.2

Fig 4. Hypotheses that emerged from Evason's interview about how the CURE supported her research and SciComm skill development.

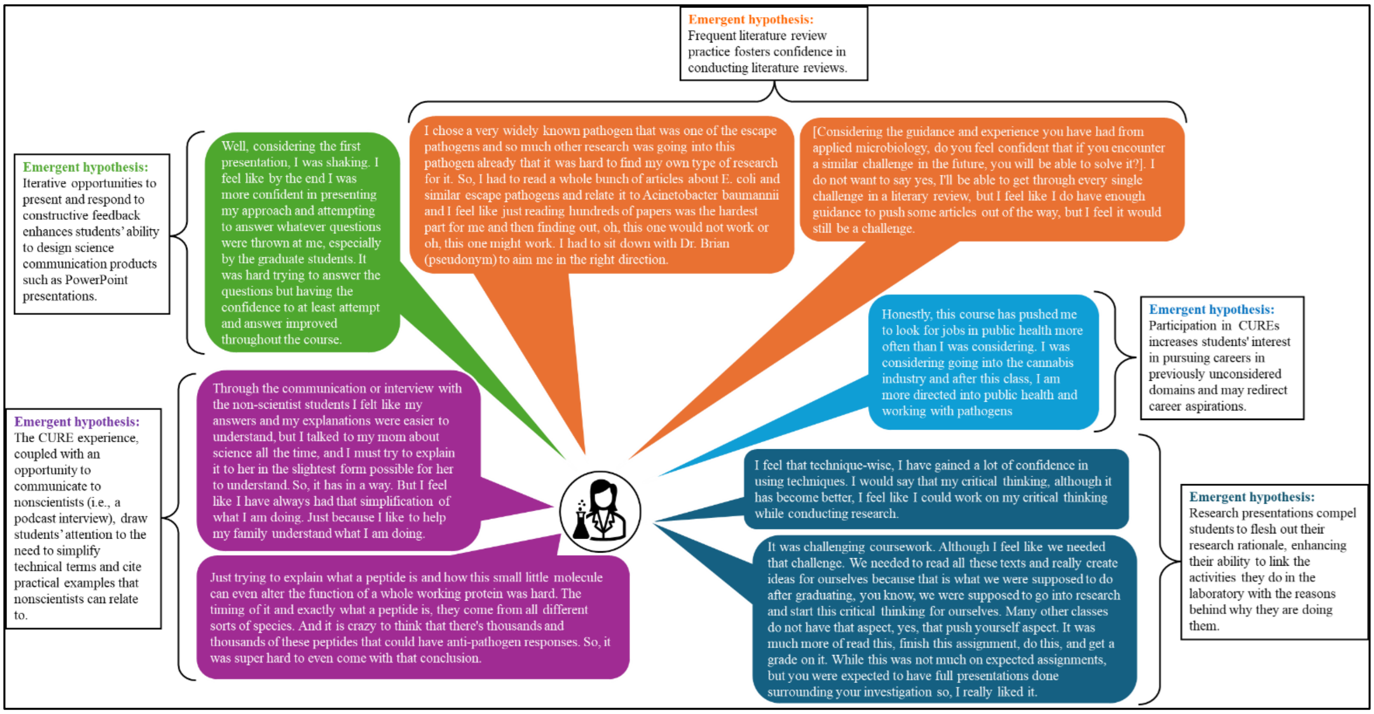


Table 4. Summary of communication features during students' non-science audience communication (i.e., podcast) that exhibited high, moderate, and little gain. Italicized features are from the Murdock (2017) rubric, while all others arise from the Sevian and Gonsalves (2008) rubric.

Higher gains (Mean > 3.5)	**Moderate gains (Mean 3.0 – 3.49)**	**Little or no gains (Mean < 3.0)**
Response to audience or engagement skills	*Ability to communicate the relevance and importance of their research*	Scaffolding explanation
Clear choice of language	Factual knowledge	Use of mental images to support explanations
Ability to explain science process	How knowledge is understood	Tactical use of media
Ability to transfer knowledge to broader context	*Trustworthy, confidence and personable*	

Conclusion

Based on students' gains on the ERLA, the CURE did not improve research confidence and independence, research identity, non-science audience communication skills, and equity, diversity, and inclusion awareness. However, science audience communication, experimental research skills confidence, researcher ethics and identity, researcher comprehension and communication, and practical research skills improved (Figure 2). Gains have been reported in all these areas (Auchincloss et. al., 2017, Brownell, 2014, Lopatto et al., 2014, Jordan et al., 2014), but we found contrasting evidence. It is possible that students reported higher pre-course skills but when the complexity involved in research was experienced, a more informed estimate of skill level was reported. Corwin et al. (2015) categorized CURE gains into short-, medium-, and long-term outcomes, indicating that the duration of a CURE significantly impacts student gains. Enhanced communication, practical research, and technical skills (i.e., short-term outcomes) were realized in this study. The short duration of the CURE impacted students' ability to make gains in areas that may require longer engagement. According to the CURE-Comm Framework (Authors, in press), the model's efficacy in enhancing SciComm skills rests on frequency of iterations between communicating and acting upon feedback. Our study reveals a correlation between repeated practice and improved science communication skills (Figure 3). Students showed gains in communicating with science audiences after three formative feedback sessions, whereas a single opportunity for non-science audience communication did not allow for learning from feedback.

With students reporting gains in only their science audience SciComm (Figure 2), all except one student improved in audience engagement, use of media to support explanations, choice of language and audience-appropriate language, and communication product design. The most dramatic improvement was observed in student 5, who improved between each presentation (Figure 3, Table 2). Interestingly, student 5 had the lowest score in the first presentation but highest score in the final presentation (Figure 3). Unique to this CURE is the oral and written constructive feedback each student received from their peers, instructor, and an independent observer. This provided frequent opportunities to practice SciComm and receive and act on feedback, leading to drastic improvement such as that observed in Student 5 (Figure 3, Table 2).

Initially, the comparison group's communication was higher than CURE students' presentation scores at the beginning of the course, but by the semester's end, the CURE group achieved significantly higher mean scores than the comparison group's single presentation, demonstrating the effectiveness of CURE activities in enhancing SciComm skills.

Students' podcast interviews showed varying gains in non-science audience communication skills (Table 4). Students excelled in responding to the audience, language choice, explaining science processes, and transferring knowledge to broader contexts. Prior experience sharing research with science audiences likely contributed to skills in these areas. Despite limited feedback opportunities, podcasting with a lay audience provided students practice developing their non-science audience communication skills.

The post-course interview with Evason revealed themes of research confidence, communication about research, communication with non-scientists, and career aspirations, allowing us to frame emergent hypotheses that should be tested empirically in the future. Compared to other courses, Evason felt the CURE involved more challenging coursework that nurtures critical thinking skills but that can be overwhelming, requiring frequent faculty interactions, clear expectations, and supervision. We put forth the emergent hypothesis that research presentations enhance students' ability to link laboratory activities to their underlying research rationale. We also hypothesize that the iterative use of lab techniques enhances confidence in technical skills but not confidence related to knowing the rationale for those lab techniques and how to apply them broadly. We recommend regular discussions of rationale and broader implications, student-led research design and implementation, and encouraging critical evaluation of experimental approaches.

Reviewing literature enhances students' research skills and fosters SciComm skills (Authors, in press), but this was a challenge for Evason. We hypothesize that frequent literature review practices foster confidence in conducting literature reviews. A guide to literature search, review, and analysis should be inculcated into the workshopping stage of the CURE to equip students with these skills. The results of the literature review could also be used to prepare communication products, which would in turn foster SciComm skills. We hypothesize that the iterative opportunities to present and respond to constructive feedback enhanced students' ability to design communication products such as PowerPoint presentations. Literature review and presentation of results to peers is an easy way to provide students with these opportunities.

Helping students in communicating with diverse audiences is the first step to effective SciComm. By incorporating podcast interviews, students confronted challenges in explaining technical terms to non-science audiences, prompting them to simplify language and use relatable examples. In response to this, we hypothesize that the CURE experience, coupled with the opportunity to communicate that science with a nonscience audience, compel students to simplify technical terms and cite practical, relatable examples. We recommend teaching audience selection strategies, customization of communication products, and culturally sensitive language during the workshopping stages.

This study addresses a critical methodological limitation in the CURE and SciComm literatures by documenting the impact of CUREs on SciComm skills. By employing a rubric to assess in-class presentations and podcast interviews, we collected empirical data that enhances the validity and reliability of our findings. Notably, this study pioneers the assessment of SciComm skills during a CURE, making it the first to provide empirical evidence of CUREs' effects on undergraduate students' SciComm skills. Despite limitations, our study demonstrates the CURE-Comm Framework's potential to achieve CURE outcomes, significantly improving students' diverse audiences' SciComm skills.

Acknowledgements

This study was conducted with approval by the Illinois State University Institutional Review Board (IRB-2021-283). Funding was generously provided for this study by the Center of Mathematics, Science, and Technology (CeMaST) and the School of Biological Science's Weigel Grant (2023/2024). I give my sincere gratitude to the applied microbiology instructor and students who, through their time, effort, and commitment, contributed to this project's success.

References

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. (2011). *Science for all Americans*. Oxford University Press. http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

ANVARI, F., EFENDIĆ, E., OLSEN, J., ARSLAN, R. C., ELSON, M., & SCHNEIDER, I. K. (2022). Bias in Self-Reports: An Initial Elevation Phenomenon. S*ocial Psychological and Personality Science, 14*(6), 194855062211291. https://doi.org/10.1177/19485506221129160

AUCHINCLOSS, L. C., LAURSEN, S. L., BRANCHAW, J. L., EAGAN, K., GRAHAM, M., HANAUER, D. I., ... & DOLAN, E. L. (2017). Assessment of Course-based Undergraduate Research Experiences: A Meeting Report. *CBE—Life Sciences Education, 13*(1), 29-40. https://doi.org/10.1187/cbe.14-01-0004

AUTHORS. (In press). The CURE-Comm Framework: A guide for infusing CUREs with science communication. *Journal of College Science Teaching*.

BANGERA, G., & BROWNELL, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE life Sciences Education*, *13*(4), 602–606. https://doi.org/10.1187/cbe.14-06-0099

BEARMAN, M., SMITH, C. D., CARBONE, A., SLADE, S., BAIK, C., HUGHES-WARRINGTON, M., & NEUMANN, D. L. (2012). Systematic Review Methodology in Higher Education. *Higher Education Research & Development, 31*(5), 625-640.

https://doi.org/10.1080/07294360.2012.702735

BROWNELL, S. E., & KLOSER, M. J. (2015). Toward a conceptual framework for measuring the effectiveness of course-based undergraduate research experiences in undergraduate biology. *Studies in Higher Education*, 40(3), 525–544.

https://doi.org/10.1080/03075079.2015.1004234

BROWNELL, S. E., KLOSER, M. J., FUKAMI, T., & SHAVELSON, R. (2012). Undergraduate biology lab courses: Comparing the impact of traditionally based "cookbook" and authentic research-based courses on student lab experiences. *Journal of College Science Teaching*, 41(4), 36–45

BROWNELL, S. E., PRICE, J. V., & STEINMAN, L. (2013b). A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. *Advance Physiology Education* *37*(1), 70-79. https://doi.org/10.1152/advan.00138.2012

BUTZ, A. R., & BRANCHAW, J. L. (2020). *Entering Research* Learning Assessment (ERLA): Validity Evidence for an Instrument to Measure Undergraduate and Graduate Research Trainee Development. *CBE Life Sciences Education*, *19*(2), ar18. https://doi.org/10.1187/cbe.19-07-0146

CARTER, N., BRYANT-LUKOSIUS, D., DICENSO, A., BLYTHE, J., & NEVILLE, A. J. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum*, *41*(5), 545–547. https://doi.org/10.1188/14.ONF.545-547

CLARKE, V., & BRAUN, V. (2016). Thematic analysis. *Journal of Positive Psychology*, *12*(3), 297–298. https://doi.org/10.1080/17439760.2016.1262613

COHEN, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155

CORWIN, L. A., GRAHAM, M. J., & DOLAN, E. L. (2015). Modeling course-based undergraduate research experiences: an agenda for future research and evaluation. *CBE Life Sciences Education*, 14(1), es1. https://doi.org/10.1187/cbe.14-10-0167

COUNCIL, N. R. (2013). Next generation science Standards. *The National Academies.*

DE PAOR, S., & HERAVI, B. (2020). Information literacy and fake news: How the field of librarianship can help combat the epidemic of fake news. *The Journal of Academic Librarianship*, *46*(5), 102218. https://doi.org/10.1016/j.acalib.2020.102218

DOLAN, E.L. (2016). Course-based Undergraduate Research Experiences: Current Knowledge and Future Directions. Paper commissioned for the Committee on Strengthening Research Experiences for Undergraduate STEM Students.

HENNICK, M. M. (2014). Focus group discussions. New York: Oxford University Press.

ING, B., J. M., AZZAM, T., & WESSLER, S. R. (2021). Participation in a Course-Based Undergraduate Research Experience Results in Higher Grades in the Companion Lecture Course. *Educational Researcher a Publication of the American Educational Research Association., 50*(4), 205–214.

MERRIAM, S. (2009). Qualitative research: A guide to design and implementation. San Francisco, CA: Jossey-Bass.

MURDOCK, R. C. (2017). An instrument for assessing the public communication of scientists. U*niversity Digital Repository*. https://dr.lib.iastate.edu/handle/20.500.12876/29769

NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE. (2017). *Communicating Science Effectively: A Research Agenda. Washington, DC: The National Academies Press. doi: 10.17226/23674.*

National Academies of Sciences, Engineering, and Medicine. (2017). *Communicating Science Effectively: A Research Agenda.* Washington, DC: The National Academy Press. http://doi:10.17226/2367

REYNA V. F. (2021). A scientific theory of gist communication and misinformation resistance, with implications for health, education, and policy. *Proceedings of the National Academy of Sciences of the United States of America, 118*(15), e1912441117. https://doi.org/10.1073/pnas.1912441117

SEVIAN, H. & GONSALVES, L. (2008). Analyzing How Scientists Explain Their Research: A Rubric for Measuring the Effectiveness of Scientific Explanations. *International Journal of Science Education, 30*(11), 1441-467. https://doi.org/10.1080/09500690802267579

SEYMOUR, E., HUNTER, A. B., LAURSEN, S. L., & DEANTONI, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. *Sci Educ 88*, 493534. https://doi.org/10.1002/sce.10131

SHAFFER, C. D., ALVAREZ, C. J., BEDNARSKI, A. E., DUNBAR, D., GOODMAN, A. L., REINKE, C., ROSENWALD, A. G., WOLYNIAK, M. J., BAILEY, C., BARNARD, D., ET AL. (2014). A Course-Based Research Experience: How Benefits Change with Increased Investment in Instructional Time. *CBE Life Sciences Education*. 13, 111–130.

https://doi.org/10.1187/cbe-13-08-0152

SHAH, H., SIMEON, J., FISHER, K. Q., &EDDY, S. L. (2022). Talking science: undergraduates' everyday conversations as acts of boundary spanning that connect science to local communities. *CBE Life Sci. Educ. 21*:ar12. https://doi:10.1187/cbe.21-06-0151

SMALL WORLD INITIATIVE, INC. 2024. Small World Initiative: Crowdsourcing Antibiotic Discovery. https://www.smallworldinitiative.org/

WEI, C.A., & WOODIN, T. (2011). Undergraduate research experience in biology: alternatives to the apprenticeship model. *CBE Life Sci Educ 10*(2), 123–131.

https://doi.org/10.1187/cbe.11-03-0028

Innovations

A Framework for Scaling-up Community-Engaged Research Experiences in Introductory General Biology Laboratories

Eva N. Nyutu[1*], Víctor Carmona-Galindo[1], and Maris Polanco[1]

Department of Biology, University of Detroit Mercy, Detroit, USA
Corresponding author: nyutuen@udmercy.edu

Abstract

In this paper, we describe the transition of all five course-sections of General Biology Laboratory I from "cookbook" surveys of taxonomic domains and kingdoms to course-based undergraduate research experiences that champion inquiry-based learning in "real world" environments. We achieved this by scaling-up lessons from a research-focused pilot section refined over three years to blend instruction with collaboration with community partners seamlessly. In terms of outcomes, students share data analyses directly with community partners, present posters at research conferences, publish research findings, and use project findings to successfully compete for placement in advanced summer research programs. This course structure benefits the students, the community partners, and the instructor. The community partners, in turn, are provided with free scientific consultations that advance data-driven strategies and empower adaptive management of localized environmental issues. The instructors benefit from the opportunity to contribute their unique disciplinary expertise toward the collaborative design and shared success of a modular complete sentence.

Key words: community engaged CURE labs, undergraduate, introductory biology, implementation, scaling up

Introduction

Most introductory biology laboratories are taught using direct instruction, where students are given predetermined answers after following procedures (Dolan, 2016; Indorf et al., 2019). This is the case with the introductory general biology laboratory courses for all first-year students at University of Detroit Mercy (UDM) which are all taught using direct instruction except for one pilot Course-Based Undergraduate Research (CURE) laboratory. At most universities, an introductory biology laboratory course is a required class for all students (biology majors and non-majors) (Baker, 2004; Gasiewski et al., 2012; Patchen et al., 2014; Robinson, 2012). For many students, an introductory biology laboratory course fulfills a credit requirement for their degree, and these may be the only science courses they will take in college (Gasiewski et al., 2012; Patchen et al., 2014; Seymour & Hewitt, 1997). For other students, these introductory biology courses serve as gateways to more advanced biology courses. Whatever the case, these introductory biology laboratory courses often lack engaging pedagogy as they heavily rely on teaching using the direct instructional approach, and this is considered one of the reasons why students switch out of biology majors (Gasiewski et al., 2012; Robinson, 2012; Garcia & Rahman, 2015). It is within the first two years of taking these courses that the majority of attrition in the sciences occurs in college (Chang et al., 2008; Seymour & Hewitt, 1997). Many students are challenged by introductory biology laboratory courses and struggle to understand and apply the content (Ateh & Charpentier, 2014; Gasiewski et al., 2012; Patchen et al., 2014). These introductory biology courses may be a critical barrier to students' progress toward their degree aspirations (Ateh & Charpentier, 2014).

Both the Vision and Change in Undergraduate Biology Report and the American Association for the Advancement of Science advocate the reform of undergraduate Science, Technology, Engineering, and Mathematics (STEM) curricula to focus on developing analytical skills instead of memorizing content (Brewer & Smith, 2011; National Research Council, 1996, 2003; Olson & Riordan, 2012). These scientific organizations and committees have called for institutions to teach science the way it is performed by professional scientists, with an emphasis on inquiry, autonomy, and discovery-based experiences (Brewer & Smith, 2011; National Research Council, 1996, 2003; Olson & Riordan, 2012). Experience with authentic research, active learning, collaborative learning communities, where, students share an intellectual experience, and involvement in research that directly impacts their scientific or local communities are some of the attributes of undergraduate programs that have met this goal (Seymour & Hewitt, 1997; Estrada et al., 2011;

Graham et al., 2013; Provost, 2016; Toven-Lindsey et al., 2015). Moreover, researchers have shown that exposing undergraduates to research experiences via faculty-supervised undergraduate research laboratories has several benefits (Werth et al., 2022). Unfortunately, such opportunities are typically available to only a few undergraduates pursuing independent research projects under the guidance of research faculty. One approach geared toward making research opportunities available for ALL students involves incorporating CUREs into the existing gateway laboratory courses that are part of the undergraduate curriculum (Brewer & Smith, 2011; Olson & Riordan, 2012, Indorf et al.,2019; Wei & Woodin, 2011; Miller et al., 2022; Werth et al., 2022). CUREs in the natural sciences (e.g., biology, chemistry, physics, math, and earth science) constitute (1) presenting an element of discovery so that students are engaged in novel exploration; (2) incorporating iteration into the course; (3) promoting collaboration among students and faculty members; (4) training students in scientific practices and critical thinking; (5) addressing research questions that are of interest to a scientific or local community (Dolan, 2016; Patchen et al., 2014, Hatfull et al., 2006; Olson & Riordan, 2012; Corwin et al., 2015; Spell et al., 2014). CUREs also present marked benefits for instructors, departments, and institutions, including student retention and the creation and collection of research data which are publishable (Brewer & Smith, 2011; Govindan et al., 2020; Jordan et al., 2014; Miller et al., 2022).

Specifically, scaling-up of existing CUREs has the potential to make research opportunities available to ALL students who do not typically access research, including those with lower GPAs and underrepresented students in STEM (Miller et al., 2022; Hydorn, 2005). CURE courses have demonstrated positive impacts on undergraduate students, including increased knowledge and skills, engaging students more actively in their learning, improved student achievement, improved preparation and persistence for STEM careers, and greater inclusion of underrepresented minorities in undergraduate research (Harrison et al.,2011 Miller et al., 2022; Freeman et al., 2014; Goodwin et al., 2021; Kuh, 2008; Hunter et al., 2007; Kardash et al., 2008; Lopatto, 2004). The more students participate in hands-on, authentic research experiences, the more likely they are to maintain their interest in science and begin to think of themselves as scientists (Mraz-Craig et al.,2018; National Academies of Sciences, Engineering, and Medicine, 2015; Archer & DeWitt, 2016; Carlone & Johnson, 2007; Dolan, 2016). Thus, the implementation of authentic CUREs may facilitate students' development of a scientific identity (Garcia et al., 2015; Chen & Soldner, 2013; Wong, 2015; Chemers et al., 2011; Hauwiller et al., 2019; Clark et al., 2016; Archer & DeWitt, 2016; Brownell et al., 2012). Several studies have shown that students who consider themselves scientists or who have a scientific identity are more likely to remain in STEM fields (Brownell et al., 2012; King et al., 2016; Lopatto, 2004; Beck, 2012; Domin, 1999; Indorf et al., 2019). The primary educational literature clearly shows that early exposure to STEM research is critical for developing and cultivating STEM interest among undergraduates, ultimately diversifying the community of students gaining access to post-graduate programs and the STEM workforce (Indorf et al., 2019). This is critical because many undergraduate students leave STEM programs within the first two years of college, with underrepresented students leaving at higher rates (Jordan et al., 2014; Carlone & Johnson, 2007). Lots of repetition. Can be cut to make it more concise.

Current biology laboratory curriculum

The UDM has been trying to improve the Introductory Biology Laboratory Curriculum General Biology Laboratory I for over 20 years (Baker, 2004). But the laboratory activities that were implemented were direct instruction confirmatory laboratory models (Batzli, 2005; Bolsenga & Herdendorf, 1993; Renkly &Bertolini, 2018). A common perception of direct instruction laboratories is that the instructor introduces the topic, presents the theoretical aspects of procedures, and identifies the laboratory objectives. The typical laboratory manual explicitly states the experimental goals of the experiment and provides instructions for data collection and analysis (Domin,1999). Within the laboratory manual, there are questions and suggestions that enable students to consider the concepts relevant to their investigations and to evaluate their experimental procedures. The students follow the procedures given by the instructor or from the laboratory manual to obtain the predetermined outcomes. Sometimes the students are unaware of the expected outcome, and the teacher directs or helps them obtain the desired outcome (Hiemstra & Van Yperen, 2015; Stufflebeam, 1983). Such direct instruction laboratories are not favored for a number of reasons: the focus of students is obtaining the correct results of the experiment though they may fail to understand the concept of the laboratory experiment (Batzli, 2005; Stufflebeam, 1983). One barrier for resource-challenged private undergraduate institutions, such as the UDM, is the prioritization of an institution-wide analysis of all programs and facilities.

To address these challenges, we developed a collaborative project to transition all five course-sections of General Biology Laboratory I from "cookbook" surveys of taxonomic domains and kingdoms that celebrate rote-memorization (National Research Council, 1996) to that of course-based undergraduate research experiences that champion inquiry-based learning in "real world" environments (Renkly & Bertolini, 2018). We would achieve this by scaling-up lessons from a pilot-section that for three years has been cultivating best practices with community partners in Detroit amidst unprecedented interruptions to Higher Education brought-on during the SARS-Cov-2 pandemic. Each Fall, General Biology Laboratory I services 180 (predominantly first year) undergraduate students from multiple departments across the College of Engineering and Science. The pilot community engaged CURE curriculum also includes exercises in reading and understanding primary literature, using various data analysis, and communicating science to different audiences. The community engaged CURE course is intended for undergraduates in their first year who are pursuing majors such as biology and pre-health. Here, we describe our collaborative model as a widely implementable curricular framework to scale up a one-semester introductory General Biology Laboratory I curriculum to employ techniques of CUREs.

Purpose

Each laboratory section of the community engaged-CURE starts with a novel issue the community partners face. The students then work on how to design an experiment around that issue so that each group of four students are working on a different issue. The community engaged-CURE has been designed to not only address particular research questions but also expose students to a variety of research techniques and topics. Upon completing the community engaged -CURE, students should achieve the following learning objectives.

- Students will be able to formulate biologically relevant questions, make empirical hypotheses, design experiments that employ independent/ dependent variables as well as controls and treatments, as well as interpret patterns in data through basic statistical analyses.
- Students will be able to make quantitative measurements of cell morphologies using a microscope and image analysis.
- Students will be able evaluate differences in the morphology of bacteria and fungi that grow on nutrient agar plates, as well as use molecular tools for the quantification of fecal-indicator bacteria in field conditions.
- Students will have a greater appreciation for the linkages between science and society.
- Compose and revise scientific manuscripts and make oral presentations that effectively communicate the findings of their research.
- Gain an increased appreciation and understanding of how hypothesis-driven research is conducted.

Our semester-long General Biology I laboratory pilot community engaged CURE course comprised two modules that build upon the preceding module's experiences. During the summer of 2021 we reimagined on how to scale up the pilot to two other sections each with 36 students. Weekly requirements included students developing a hypothesis, designing, and setting up an experiment, collecting data, recording results, and forming conclusions that highlighted how they applied scientific methodology (see Appendix 1). Using an empirical, experimental approach (i.e., hypothesis testing), the first module project empowers students to select the independent variables, the second module allows both dependent and independent variables to be selected by students. The first module we partnered with Cadillac Urban Gardens to focus on photosynthesis and climate change. For the second module, we worked with Lake St. Clair Metro Park on microbial diversity, addressing green stormwater infrastructure. Benefits include ease of getting to the locations which are close to campus, many of the students live in the communities where our partners are based, and students' experience using their STEM degree to cultivate change in their community. Students participate in a project that follows the typical topics/concepts covered in the lecture, from photosynthesis to central dogma, scientific method, microbial diversity, and classification systems in one semester, providing a strong connection between the topics discussed in the introductory biology lecture and the hands-on aspect of the research experience.

In module one, students learn the basic principles of the compound microscopes (see Appendix 1). Calibration of ocular micrometers, measurements of microscopic structures and preparation. Once students have mastered these skills they will collect two leaves from an oak tree and two leaves from the cherry trees outside the biology department. The students measured the stomata length, stomata density, and percentage of stomata open and closed. The students typed in their data in a shared excel file and then calculated, mean, standard deviation and run a T-test. Then graphed their data using excel and recorded their data in their electronic OneNote notebook. The following week, students sampled stomatal densities of plants at Cadillac Urban Gardens Southwest Detroit Environmental Vision. Cadillac Urban Gardens is a one-acre urban garden located in, Southwest Detroit, on the former grounds of the Cadillac Clark Street Plant's Executive parking lot. In 2012 as a community collaboration between Southwest Detroit Environmental Vision (SDEV), the Ideal Group, General Motors (GM), residents, non-profits, businesses, schools, and other local community organizations, Cadillac Urban Gardens was developed with and for the community in mind. This garden since 2012 has been able to repurpose 331 shipping containers from GM and utilize them as raised beds to grow fresh produce the community can harvest without cost. The garden provides food security for residents with little access to garden space and fresh produce. It has become a model for sustainable gardening practices as residents grow and harvest produce within walking distance of their homes. Thus, students developed a research project responding to an environmental issue that Cadillac Urban Gardens Southwest Detroit Environmental Vision had identified as affecting their plants. For example, is there a difference in the stomatal density of companion plants and plants grown alone without companion plants in raised beds. The students recorded their data in their OneNote electronic laboratory book. Students analyzed their data and prepared their scientific poster which they presented at the College of Engineering and Science Undergraduate Research Presentation at UDM.

In the second module students learned about microbial diversity and richness (see Appendix 1). In the prior week students prepared 12 tryptone soya agar (TSA) and 12 Lennox broth (LB) agar petri plates. As students waited for their liquid agars to solidify, they went over the Shannon Index Diversity. The students went around campus and compared faculty and student's car diversity (car type and car color) to practice on how to calculate and analyze data using the Shannon Index Diversity. The following week students went around campus and came up with two creative places where they swabbed for bacteria and inoculated them in the TSA and LB agar plates they had prepared and incubated the agar plates for a week. The subsequent week, students made a library of the different morphology of the different bacterial species they identified on their LB and TSA agar plates and saved them in their electronic OneNote notebook. The students used Acrobat reader image analysis tool to digitally measure the area of all bacterial colonies and then record their data in excel. The students then used EstimateS to rarefy their data, and use excel to make graphs of their data, and prepared their scientific poster. The following week the students collected data from Lake St. Clair Metropark inherent in this goal was to have students experience an impaired watershed in multiple ways by physically touring and observing environmental impacts in the watershed, sampling, and testing different sites for physical/chemical parameters, and quantifying Escherichia coli and coliform colony forming units (CFUs). In this module students also developed a laboratory project connecting student learning to real-life challenges, specifically a local water-quality project. This module will focus on water quality issues which are important community concerns in metropolitan Detroit (Renkly & Bertolini, 2018).

The green scaping project is a solution to stormwater pollution that residents have been concerned about for years. The ponds and vegetation bioswales collect the rainwater as it falls and naturally filter out the contaminants before the water flows back into Lake St. Clair. The Lake St. Clair Metro Park project is a great starting point for further green infrastructure development in Macomb County. Students collected water samples from different points on Lake St. Clair to test for levels of Escherichia coli and total coliform.

After collecting their water samples in 100ml disposable sterile sampling vials. The students put one packet of the colilert reagent in each water bottle and mixed it until the colilert reagent dissolved. The students then poured out the mixture in Quanti tray sleeves and sealed each sleeve using the Quanti-tray IDEXX sealer. The sealed trays were placed in a 35°C incubator for 24 hours. The students counted the number of positive wells for Escherichia coli and coliform and used the table provided with the IDEXX sealer to obtain a Most Probable Number (MPN) and recorded their results in a shared excel file. The students then ran a correlation analysis between the Most Probable Number and the physical properties of water (Total Suspended Solid, Temperature, pH, and Conductivity), T-test to compare the means of the two different sites those with invasive Phragmites and those without Phragmites. The students recorded their data in their OneNote electronic laboratory book. Students prepared their scientific poster and presented to the class and the community partners.

Conclusions

Scaling-up the piloted community engaged CURE best-practices across all the General Biology I laboratory sections resulted in informative experiences for first-year undergraduates in the college stemming from an "asset-based" STEM culture (i.e., strengths driven), which celebrates inclusive excellence by placing it (e.g., collaborative partnerships, language skills, cultural backgrounds, etc.) at the forefront of scientific exploration and innovation (Olson & Riordan, 2012). For example, while many of the students in the pilot courses lived in the communities where our partners were based, student evaluations showed it was the first time most of them experienced using their STEM degree to cultivate change. These community-engaged research experiences stand in sharp contrast to the "deficit-based" approach (i.e., needs-driven) students experienced throughout high school, wherein STEM contributions were reduced to memorization of facts detached from students' personal sphere of influence or interest (National Research Council, 2003). This collaborative project piloted course structure allows faculty to mentor short-term field projects (i.e., student explorations) that serve as a research strategy for the long-term study of diverse biological phenomena in an urban context. As teacher-scholars in a Primarily Undergraduate Institution, this collaborative project will sustain vibrant and academically productive scholarship with student co-authored contributions and cultivate grantsmanship by advancing pilot data primed for competitive federal and foundation grants. This collaborative project also democratizes research mentorship for a broader segment of the student community, many of whom may not have approached a professor on their own to seek out research opportunities in a faculty laboratory. Another significant result from these community engaged CURES is that more diverse group of undergraduate students can now advance highly competitive dossiers when applying to graduate and professional programs. This community engaged CURE laboratory provides an affordable option for colleges of all sizes to provide students an off-site course-based research experience. One feature of the community engaged-CURE is the adaptability of the project into a semester schedule.

In terms of outcomes, students share data analyses directly with community partners, presented posters at research conferences (e.g., College of Engineering & Science), will publish research findings (e.g., Michigan Academy of Sciences, Arts, and Letters), and use project findings to successfully compete for placement in advanced summer research programs (e.g., Biology Summer Internships). This course structure benefits the students, the community partners, and the instructor. It grants students access to independent research and opportunities to publish authentic scientific papers as undergraduates. The community partners, in turn, are provided with free scientific consultations that advance data-driven strategies and empower adaptive management of localized environmental issues. The instructor benefits from the opportunity to contribute their unique disciplinary expertise toward the collaborative design and shared success of a modular learning structure. Advancing hands-on research explorations that tackle real-world problems affecting diverse Detroit-area communities, our proposed course model has the potential to tap diverse perspectives in solving local environmental challenges as well as identifying innovative new directions of STEM research. By enhancing early participation and removing barriers to research experiences, community-engaged CUREs at the introductory level also help students enter upper-division courses with a greater understanding and expectation of research experiences and its transformative role in society. Additionally, by empowering undergraduates in the design and scope of STEM explorations that address environmental issues affecting Detroit-area communities, we feel a community engaged CURE model serves as an effective strategy for improving the recruitment and retention of underrepresented students in STEM disciplines.

Acknowledgments

We are grateful to UDM for providing the opportunity to implement this core component of the laboratory curriculum. The authors declare that they have no conflicts of interest.

References

ARCHER, L., & DEWITT, J. (2016). Understanding Young People's Science Aspirations: How students form ideas about 'becoming a scientist'. Taylor & Francis.

ATEH, C. M., & CHARPENTIER, A. (2014). Sustaining student engagement in learning science. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 87(6), 259-263.

BAKER, S. S. (2004). Using transgenic Arabidopsis in cold acclimation experiments is an effective tool in teaching the process of science. 26th Annual Association of Biology Laboratory Educations Conference. Bowling Green, OH.

BANGERA, G., & BROWNELL, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. CBE—Life Sciences Education, 13(4), 602-606.

BATZLI, J. M. (2005). Points of view: A survey of survey courses: Are they effective? A unique approach? Four semesters of biology core curriculum. Cell Biology Education, 4(2), 125-128.

BECK, K. 2012. The Effect of Guided-Inquiry Chemistry Labs on Student Engagement. Master Thesis, Carroll University WI

BOLSENGA, S. J., & HERDENDORF, C.E. (Eds.). (1993). Lake Erie and Lake St. Clair Handbook. Wayne State University Press.

BREWER, C. A., & SMITH, D. (2011). Vision and change in undergraduate biology education: a call to action. American Association for the Advancement of Science, Washington, DC, 81.

BROWNELL, S. E., KLOSER, M. J., FUKAMI, T., & SHAVELSON, R. (2012). Undergraduate biology lab courses: comparing the impact of traditionally based "cookbook" and authentic research-based courses on student lab experiences. Journal of College Science Teaching, 41(4), 36-45.

CARLONE, H. B., & JOHNSON, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 44(8), 1187-1218.

CHANG, M. J., CERNA, O., HAN, J., & SAENZ, V. (2008). The contradictory roles of institutional status in retaining underrepresented minorities in biomedical and behavioral science majors. The Review of Higher Education, 31(4), 433-464.

CHEMERS, M. M., ZURBRIGGEN, E. L., SYED, M., GOZA, B. K., & BEARMAN, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. Journal of Social Issues, 67(3), 469-491.

CHEN, X. (2013). STEM Attrition: College Students' Paths into and out of STEM Fields. Statistical Analysis Report. NCES 2014-001. National Center for Education Statistics.

CLARK, T. M., RICCIARDO, R., & WEAVER, T. (2016). Transitioning from expository laboratory experiments to course-based undergraduate research in general chemistry. Journal of Chemical Education, 93(1), 56-63.

CORWIN, L. A., GRAHAM, M. J., & DOLAN, E. L. (2015). Modeling course-based undergraduate research experiences: An agenda for future research and evaluation. CBE—Life Sciences Education, 14(1), es1.

DOLAN, E. L. (2016). Course-based undergraduate research experiences: Current knowledge and future directions. Natl Res Counc Comm Pap, 1, 1-34.

DOMIN, D. S. (1999). A review of laboratory instruction styles. Journal of chemical education, 76(4), 543.

ESTRADA, M., WOODCOCK, A., HERNANDEZ, P. R., & SCHULTZ, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. Journal of educational psychology, 103(1), 206.

FREEMAN, S., EDDY, S. L., MCDONOUGH, M., SMITH, M. K., OKOROAFOR, N., JORDT, H., & WENDEROTH, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the national academy of sciences, 111(23), 8410-8415. Uppercase-National Academy of Sciences

GARCIA, R., RAHMAN, A., & KLEIN, J. G. (2015). Engaging Non–Science Majors in Biology, One Disease at a Time. The American Biology Teacher, 77(3), 178-183.

GASIEWSKI, J. A., EAGAN, M. K., GARCIA, G. A., HURTADO, S., & CHANG, M. J. (2012). From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. Research in higher education, 53, 229-261.

GOODWIN, E. C., ANOKHIN, V., GRAY, M. J., ZAJIC, D. E., PODRABSKY, J. E., & SHORTLIDGE, E. E. (2021). Is this science? Students' experiences of failure make a research-based course feel authentic. CBE—Life Sciences Education, 20(1), ar10.

GOVINDAN, B., PICKETT, S., & RIGGS, B. (2020). Fear of the CURE: a beginner's guide to overcoming barriers in creating a course-based undergraduate research experience. Journal of microbiology & biology education, 21(2), 50.

GRAHAM, M. J., FREDERICK, J., BYARS-WINSTON, A., HUNTER, A. B., & HANDELSMAN, J. (2013). Increasing persistence of college students in STEM. Science, 341(6153), 1455-1456.

HARRISON, M., DUNBAR, D., RATMANSKY, L., BOYD, K., & LOPATTO, D. (2011). Classroom-based science research at the introductory level: changes in career choices and attitude. CBE—Life Sciences Education, 10(3), 279-286.

HATFULL, G. F., PEDULLA, M. L., JACOBS-SERA, D., CICHON, P. M., FOLEY, A., FORD, M. E., ... & HENDRIX, R. W. (2006). Exploring the mycobacteriophage metaproteome: phage genomics as an educational platform. PLoS genetics, 2(6), e92.

HAUWILLER, M. R., ONDRY, J. C., CALVIN, J. J., BARANGER, A. M., & ALIVISATOS, A. P. (2019). Translatable research group-based undergraduate research program for lower-division students. Journal of chemical education, 96(9), 1881-1890.

HIEMSTRA, D., & VAN YPEREN, N. W. (2015). The effects of strength-based versus deficit-based self-regulated learning strategies on students' effort intentions. Motivation and Emotion, 39, 656-668.

HUNTER, A. B., LAURSEN, S. L., & SEYMOUR, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. Science education, 91(1), 36-74.

HYDORN, D. L. (2005). Community service projects in a first statistics course. MAA NOTES, 66, 111.

INDORF, J. L., WEREMIJEWICZ, J., JANOS, D. P., & GAINES, M. S. (2019). Adding authenticity to inquiry in a first-year, research-based, biology laboratory course. CBE—Life Sciences Education, 18(3), ar38.

JOHNSON, T. R., & CASE, C.L. (2013). Laboratory experiments in microbiology. 10th ed. Benjamin Cummings; San Francisco, CA: 2013.

JORDAN, T. C., BURNETT, S. H., CARSON, S., CARUSO, S. M., CLASE, K., DEJONG, R. J., ... & HATFULL, G. F. (2014). A broadly implementable research course in phage discovery and genomics for first-year undergraduate students. MBio, 5(1), e01051-13.

KARDASH, C. M., WALLACE, M., & BLOCKUS, L. (2008). Undergraduate research experiences: Male and female interns' perceptions of gains, disappointments, and self-efficacy.

KING, N., VAN DER TOUW, T., SPOWART, L., & LAWLOR, C. (2016). A scoping study investigating student perceptions towards inquiry-based learning in the laboratory. European Journal of Science and Mathematics Education, 4: 305-314.

KUH, G. D. (2008). Excerpt from high-impact educational practices: What they are, who has access to them, and why they matter. Association of American Colleges and Universities, 14(3), 28-29.

LOPATTO, D. (2004). Survey of undergraduate research experiences (SURE): First findings. Cell biology education, 3(4), 270-277.

LORD, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. The American biology teacher, 68(6), 342-345.

MILLER, D. M., NATALE, A., MCANULTY, T. K., SWOPE, R. D., MCNAUGHTON, E. A., BECKETT, A., ... & XIONG, S. (2022). The Design and Implementation of an Interdisciplinary CURE as an Alternative Option for the General Chemistry Laboratory Course. Journal of Chemical Education, 99(7), 2530-2540.

MRAZ-CRAIG, J. A., DANIEL, K. L., BUCKLIN, C. J., MISHRA, C., ALI, L., & CLASE, K. L. (2018). Student identities in authentic course-based undergraduate research experience. Journal of College Science Teaching, 48(1), 68-75.

NAGDA, B. A., GREGERMAN, S. R., JONIDES, J., VON HIPPEL, W., & LERNER, J. S. (1998). Undergraduate student-faculty research partnerships affect studen retention. The Review of Higher Education, 22(1), 55-72.

NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE. (2015). Integrating discovery-based research into the undergraduate curriculum: Report of a convocation. National Academies Press.

NATIONAL RESEARCH COUNCIL. (1996). National science education standards. National Academies Press.

NATIONAL RESEARCH COUNCIL. (2003). BIO2010: Transforming undergraduate education for future research biologists. More details on the reference

OLSON, S., & RIORDAN, D. G. (2012). Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the president. Executive Office of the President.

OLSON, S., & RIORDAN, D. G. (2012). Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the president. Executive Office of the President.

PATCHEN, A. K., DEBAY, D. J., BARNETT, M., & STRAUSS, E. (2014). Engaging students in scientific inquiry: successes and challenges of engaging non-science majors in scientific inquiry. In Inquiry-based learning for faculty and institutional development: A conceptual and practical resource for educators (Vol. 1, pp. 271-289). Emerald Group Publishing Limited.

PROVOST, J. (2016). Research for all: a CURE for undergraduates. ASBMB Today, 15, 30-31.

RENKLY, S., & BERTOLINI, K. (2018). Shifting the paradigm from deficit oriented schools to asset based models: why leaders need to promote an asset orientation in our schools. Empowering Research for Educators, 2(1), 4.

ROBINSON, N. R. (2012). An evaluation of community college student perceptions of the science laboratory and attitudes towards science in an introductory biology course (Doctoral dissertation, University of Alabama Libraries).

SEYMOUR, E., & HEWITT, N. M. (1997). Talking about leaving (Vol. 34). Westview Press, Boulder, CO.

SPELL, R. M., GUINAN, J. A., MILLER, K. R., & BECK, C. W. (2014). Redefining authentic research experiences in introductory biology laboratories and barriers to their implementation. CBE—Life Sciences Education, 13(1), 102-110.

STUFFLEBEAM, D. L. (1983). The CIPP Model for Program Evaluation, in Evaluation Models. Viewpoints on Educational and Human Services Evaluation, 1983.

TOVEN-LINDSEY, B., LEVIS-FITZGERALD, M., BARBER, P. H., & HASSON, T. (2015). Increasing persistence in undergraduate science majors: A model for institutional support of underrepresented students. CBE—Life Sciences Education, 14(2), ar12.

TRAVIS, H., & LORD, T. (2004). Traditional and constructivist teaching techniques. Journal of College Science Teaching, 34(3), 12.

WEI, C. A., & WOODIN, T. (2011). Undergraduate research experiences in biology: alternatives to the apprenticeship model. CBE—Life Sciences Education, 10(2), 123-131.

WERTH, A., WEST, C. G., & LEWANDOWSKI, H. J. (2022). Impacts on student learning, confidence, and affect and in a remote, large-enrollment, course-based undergraduate research experience in physics. Physical Review Physics Education Research, 18(1), 010129.

WONG, B. (2015). Careers “From” but not “in” science: Why are aspirations to be a scientist challenging for minority ethnic students? Journal of Research in Science Teaching, 52(7), 979-1002.

Community Engaged CURE Modules

Day	Week of	Module	Recitation/ Online Lecture	Lab Activities	Assignments+
T	**Aug 29**	Climate Change	• **Climate Change**	• **Syllabus** • **25 questions**	
T	**Sep 5**	Climate Change	• **Autotrophs: Chemosynthesis & C_3/C_4/CAM photosynthesis**	• **Stomata measurements**	
T	**Sep 12**	Climate Change	**Biochemistry of Photosynthesis**	• **Experimental design** • **Data collection**	
T	**Sep 19**	Climate Change	• **Conservation Biology & Climate Change**	• **SDEV Cadillac Gardens** • **Experimental design** • **Data collection**	
T	**Sep 26**	Climate Change	• **Using the electronic resources of the library**	• **Scientific writing** • **Poster design**	• **Env. Justice Assignment Due**: Climate Change • **OneNote Notebook Check**
T	**Oct 3**	Microbial Diversity	• **DNA, Alleles, & Evolution**	• **Pour agarose gels**	• **Poster Due**: *Stomatal Dynamics*
T	**Oct 10**	Microbial Diversity	• **Central Dogma & Gene Structure**	• **Pour agarose gels** • **Experimental design**	• **PechaKucha**: *Stomatal Dynamics*
T	**Oct 17**	Microbial Diversity	• **Organismal Richness, Diversity, & Evenness**	• **Experimental design** • **Data collection**	
T	**Oct 24**	Microbial Diversity	• **Set up mini project**	• **Experimental design** • **Data collection**	
T	**Oct 31**	Microbial Diversity	• **Imaging Analysis through Adobe**	• **Scientific writing** • **Poster design**	• **Env. Justice Assignment Due**: Microbial Diversity • **OneNote Notebook Check**
T	**Nov 7**	Microbial Diversity	• **Rarefying Data and Graphing**	• **Aquaponics** • **experimental design**	• **Poster Due**: *FIB Dynamics*
T	**Nov 14**	Microbial Diversity	• **Reading Phylogenetic Trees**	• **Lake St. Clair MetroPark Raingardens** • **Data collection** • **Data analysis Data collection**	• **PechaKucha**: *FIB Dynamics*
T	**Nov 21**	***Thanksgiving Break***		•	
T	**Nov 28**	Microbial Diversity	• **Kingdoms: Features & Clades in Flux**	• **Data analysis**	
T	**Dec 5**	Microbial Diversity	• **Phylogenies & Conservation Biology**	• **Scientific writing** • **Poster design**	• **Env. Justice Assignment Due**: • **Poster Due** • **OneNote Notebook Check**
T	**Dec 14**	Microbial Diversity	**FINAL EXAM 2:00–3:50p**		• **Poster Due**: Lake St Clair • **Oral Presentation:** Lake St Clair

A Few Ideas for Biology Labs on a Budget

Robert Wolff

South University, 9 Science Ct., Columbia SC 29203

robertwolff52@gmail.com

https://orcid.org/0000-0002-0543-0558

For many small colleges in the U.S., and those schools in lower socioeconomic countries, the cost of laboratory equipment and supplies can limit teaching or make it very difficult unless an inexpensive alternative is developed. A few ideas for a few thrifty options are offered, and while they are particularly appropriate for microbiology labs, they can be used in other courses as well.

Online resources for inexpensive laboratory ideas are available, but spread out through the vast internet. Chagas, et.al. present an excellent idea for 3-D printing of an inexpensive lab set-up that can be used in teaching, and research! While requiring a 3-D printer, these are now widely available and the author's interest in "open labware" opens up many new possibilities for teaching labs.

Smartphones are widely used for assisting imaging (Raju, et.al.) at low cost and the option to build microscopes (Grier, et.al.) can allow both the inexpensive set up of a lab, but offer opportunities for students learning the basics of equipment operation.

The three simple ideas below are presented with hopes of lowering the cost of teaching laboratories, and increase the reuse of materials for a reduction in waste.

Slide Staining Trays

Trays used for staining microscope slides, especially for use with microbes, include a number of quality metal varieties which cost in the range of $ 50-100/each can be replaced with simple plastic ice cube trays. These can be obtained for as low as $ 1-2/each, and there are many varieties that can accommodate different ways to hold the slides.

These trays offer the convenience of being able to be purchased locally, can be considered disposable, and with some materials may even be able to undergo sterilization. It is easy for these trays to be drained into disposal sinks and actually are able to reduce the risk of spilling over commercial staining trays that do not have as much depth for the waste fluids.

Recommendations include purchasing trays with a bit of an outer lip to help retain the stains and rinsing fluids in the tray, making sure the slides are able to lie flat over the fillable spaces, and that the 'handles' make it easy for students to hold and move the trays. As they are plastic, with some flexibility to break the ice cubes free, they are able to withstand cracking or breaking.

Figure 1. An example of an ice cube tray that has been used for staining in a microbiology lab.

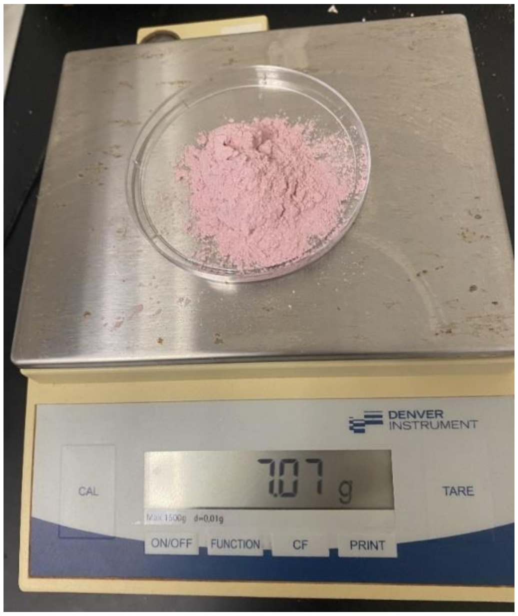
This tray is over ten years old and still functional.

Slide Holding Forceps

While slide holding forceps are available from $ 1-9/each, these can be replaced with old fashioned wooden clothespins that are readily available at $ 1-5 for fifty of these handy slide holders. They actually do last longer than the thinner wiry (bendable) holders, it can be important to obtain those that have a good grip, and that students do place them over the slides deeply for a good grip. Loosely held slides can swing out if only grabbed by the edges. The wood may become stained, but this does not affect usage, nor does some burning of the wood (though use with Bunsen burners should be monitored).

Figure 2. Wooden clothespins used as slide holders.

Figure 3. The top lid of a petri plate as a weighing dish.



Using Perti Plate Pieces for Weighing Dishes

Weighing dishes are usually not very expensive, but in emergencies when you have run out there is a simple option which is using the covers or unmatched bottoms of petri plates. Also, this is a good option if you are environmentally minded.

Often you will find a cracked plate in the sleeve of petri plates, the top from a plate of prepared media that has dried out or expired, or sometimes just the plate cover from a growth plate that is clean. A box or drawer of these is good to keep on hand for when you need a weighing dish.

References

Chagas AM, Prieto-Godino LL, Arrenberg AB & Baden T. The €100 lab: A 3D-printable open-source platform for fluorescence microscopy, optogenetics, and accurate temperature control during behaviour of zebrafish, Drosophila, and Caenorhabditis elegans. *PLOS Biology*, 2017; 15 (7): e2002702 DOI: 10.1371/journal.pbio.2002702

Grier Z, Soddu MF, Kenyatta N, Odame SA, Sanders J, Wright L, & Anselmi F. Optics education and outreach V. SPIE; 2018. A low-cost do-it-yourself microscope kit for hands-on science education; pp. 133–148. [Google Scholar]

Raju G, Ranjan A, Banik S, Poddar A, Managuli V & Mazumder N. A commentary on the development and use of smartphone imaging devices. Biophys Rev. 2023 Dec 16;16(2):151-163. doi: 10.1007/s12551-023-01175-1. PMID: 38737211; PMCID: PMC11078910.

68th Annual Meeting
October 18th- 19th, 2024
Hosted by

Marquette University
Milwaukee, WI

Local Arrangements and Program Chair

Khadijah Makky, Ph.D.
Clinical Professor
Department of Biomedical Sciences
Marquette University
Milwaukee, WI
khadijah.makky@marquette.edu

ACUBE's 68th Annual Meeting Program Overview

Most sessions take place in Raynor Library, All indicated times are Central Standard Time (CST).

Friday, October 18th

11:00 am - 1:00 pm ACUBE Steering Committee Meeting

12:00 pm - 1:00 pm Registration

1:00 pm - 1:30 pm Welcoming Remarks and Meeting Orientation

Session A- 90-Minute Workshops

1:30 pm - 3:00 pm Two Concurrent workshops

3:00 pm - 3:05 pm Break

Session B- 20- minute presentations

3:05 pm - 4:05 pm Sequential 20-minute presentations

4:05 pm - 4:10 pm Break

Session C- 40-minute presentations

4:10 pm - 5:30 pm Sequential 40-minute presentations

Evening Session - Alumni Memorial Union (AMU)

6:00 pm - 7:00 pm Poster Session and Social Hour

7:00 pm - 7:30 pm Bioscene information Session

7:30 pm - 9:00 pm Dinner, Award presentation

Saturday, October 19th

In Person-Session

8:00 am - 9:30 am Registration

8:00 am - 9:30 am Continental Breakfast- Raynor Library

8:30 am - 9:30 am Morning Brew: An Intimate Discussion on Preparing for A Teaching Career Post-PhD

Session A- 90-Minute Workshop

9:30 am - 11:00 am **90-minute Workshop**: Models and Modeling: Tools of Engagement

11:00 am - 11:05 am Break

Session B- Concurrent presentations

11:05 am - 11:45 am 40-minute presentation

11:05 am - 12:05 pm Sequential 20-minute presentations

12:05 pm - 1:15 pm Lunch and ACUBE business meeting

Keynote Speaker Workshop (hybrid presentation)

1:15 pm - 2:30 pm Keynote speaker workshop

2:35 pm - 3:05 pm Optional Q&A follow up Discussion

Virtual Sessions:

2:30 pm - 6:00 pm MS Teams Presentations

Session C- Virtual Sequential Presentations (40 minutes)

2:30 pm - 3:50 pm Sequential 40-minute presentations

3:50 pm - 3:55 pm Break

Session D- Virtual Sequential Presentations (20 minutes)

3:55 pm - 4:55 pm Sequential 20-minute presentations

4:55 pm - 5:00 pm Break

Session E- Virtual poster Presentations

5:00 pm - 5:40 pm Virtual poster presentations (different breakrooms)

5:40 pm - 6:00 pm Conference conclusion and closing remarks

6:00 pm - 7:30 pm Steering Committee meeting (for committee members)

Keynote Speaker: Dr. Julia Metzker

Biography

Dr. Julia Metzker is a passionate advocate for transformative liberal arts education, with a distinguished career in educational development, course design, and assessment. With a keen interest in developing engaging courses that are the building blocks of a transformative college experience, Julia has led initiatives to reform general education and implement successful university-wide programs. Julia's early work in science education and civic engagement created a foundation for her work in professional development focused on learning. Julia is a co-author Designing Learning Experiences that Matter: A Field Guide to Course Design for Transformative Education (2021), which received an Outstanding Book honorable mention from the Society of Professors of Education.

JuliA currently serves as the Director of the Washington Center for Improving Undergraduate Education at Evergreen. As a public service center at Evergreen, The Washington Center is a national resource to higher education institutions for creating equitable learning opportunities for all students through consulting, mentoring, activities, trainings, and initiatives. Julia received her B.S. in chemistry from The Evergreen State College and pursued her Ph.D. in inorganic chemistry at the University of Arizona.

Keynote Address:

Cultivating Inclusive and Culturally Sustaining Classrooms (What's Your Teaching Manifesto?)

This plenary talk invites participants to take their next step toward becoming inclusive and culturally sustaining educators. Through self-reflection, you will develop a teaching manifesto that articulates your vision and values. Along the way, we will explore practical strategies, such as transparent assignments, relationship-building activities, and responsive feedback techniques. We will also discuss the importance of investing in ourselves so that we have the capacity to build classroom environments where students with diverse educational histories and cultural identities feel they belong. As you navigate the day-to-day challenges of teaching when you return to the classroom, the teaching manifesto promises to be a source of inspiration, reminding you of your commitments to yourself and your students.

68th Annual ACUBE Meeting Program
Marquette University
Milwaukee, Wisconsin
October 18th-19th, 2024

Friday, October 18th, 2024	
11:00 AM - 1:00 PM Steering Committee Meeting (for committee members)	Raynor Library
12:00 PM - 1:00PM Registration / Light lunch will be provided	Raynor Library
1:00 PM - 1:30 PM Welcoming Remarks and conference information	Beaumier Suite B-C
1:30 PM - 3:00 PM Session A- Concurrent workshops (90 minutes) a- **Exploring Natural Selection in Humans Using BioInteractive's Sickle Cell Resources - for your reference.** Jonelle Orridge and Nilo Marin, Broward College b- **Investigating Climate Change through National and Local Case Studies with HHMI BioInteractive Resources"** Tara Jo Holmberg, and Melissa Haswell HHMI BioInteractive	 Beaumier Suite B-C Raynor Library 3rd floor RM330
3:00 PM - 3:05 PM Break	
3:05 PM - 4:05 PM Session B- Sequential presentations (20 minutes) a- **Emphasizing the challenges of scientific communication using an icebreaker activity** Ashley Driver, University of Scranton b- **Getting students to be "Wimpy Wimpy Wimpy:": Weekend Assignment for Key Concepts in an Anatomy and Physiology Course** Sarah Lovern, Concordia University of Wisconsin c- **U-RISE at MU's Approach to Broadening Participation in Biomedical PhD programs and Research** Laurieann Klockow, Marquette University	Beaumier Suite B-C
4:05 PM - 4:10 PM Break	
4:10 PM - 5:30 PM Session C- Sequential Presentations (40 minutes) a- **A Walk in the Park: A Botanical Field Research Project for Biology Students.** Luciana Caporaletti, Penn State University b- **Exploring Math in Biology: Perspectives of Two-Year College Educators** Kristine Squillace Stenlund, University of Minnesota and Dakota County Technical College	Beaumier Suite B-C

Friday, October 18th, 2024, Evening Session At the Alumni Memorial Union (AMU) Visitor Campus Map #61	
6:00 PM - 7:00 PM Poster session and social hours **Poster Presentations** a- **Effects of student demographics on self-identity as a scientist in course-based research modules** Christopher Yahnke, University of Wisconsin- Stevens Point b- **Leveraging the Benefits of the Digital Era: Identifying the value of Non-Traditional Learning Methods** Brook Greiner, Medical College of Wisconsin c- **Incorporating Conversations on Diversity, Equity, and Inclusion into the Undergraduate Research Experience** Gabriella Marino, Marquette University d- **Enhancing Belonging for Underrepresented Students through Student-Designed Learning Field Experiences** Brian R. Shmaefsky, Lone Star College – Kingwood	Alumni Memorial Union (AMU) - 2nd Floor
7:00 PM - 7:30 PM Bioscene Presentation	
7:30 PM - 9:00 PM Dinner and Award presentations	

Saturday, October 19th 2024	
8:00 AM- 2:30 PM **In Person Session**	
8:00 AM - 9:30 AM Registration and Continental Breakfast ***Beaumier Suite B-C*** *(at 8:30)* Graduate Students and Post-Docs Special Session **Morning Brew: An Intimate Discussion on Preparing for A Teaching Career Post PhD** Nouran Amin, Ball State University JT Cornelius, Indiana University School of Medicine, Bloomington ***Raynor Library 3rd floor RM-330***	
9:30 AM - 11:00 AM **Session A- 90-minute Workshop** a- **Models and Modeling: Tools of Engagement** Tim Herman, 3D Molecular Designs	Beaumier Suite B-C

11:00 AM - 11:05 AM Break **11:05 AM - 12:05 PM Session B- Concurrent 40- minute and 20- minute presentations** 40- minute presentation a- **Preparing Graduate Students for Teaching Through a Certificate in University Teaching Program** George Todd, University of Missouri-St. Louis 20- minute sequential presentations a- **Welcoming underrepresented minority undergraduate students into formal medical and scientific spaces.** Emma Tillison, Medical College of Wisconsin b- **Midsemester feedback is an essential tool for a first-time teacher** Carrie Hetzel, Harvard University c- **Co-Teaching to bridge the gap between introductory-level and upper-division biology courses at a four-year institution** Takunda Maisva, Syracuse University	Raynor Library 3rd floor RM-330 Beaumier Suite B-C
12:05 PM - 1:15 PM Lunch and ACUBE Business meeting	Beaumier Suite B-C
Keynote Address Dr. Julia Metzker **Director of the Washington Center for Improving Undergraduate Education at Evergreen**	
1:15 PM - 2:30 PM Keynote Address **Cultivating Inclusive and Culturally Sustaining Classrooms** **MS Teams Link: Keynote Address** **2:35 PM - 3:05 PM Optional Q&A Follow Up Discussion** Moderator: Ashley Driver, President of the ACUBE **MS Teams Link: Keynote Address Discussion to follow**	Beaumier Suite B-C Raynor Library 3rd floor RM-330

2:30 PM - 3:50PM Session C- Virtual sequential presentations (40-minutes) **MS Teams Link**: 40- and 20 minute presentations **a- An Intriguing Intersectionality: The Role of Medical Experiences and First-Generation Status** Brittney N. Wyatt, Porter Bischoff, Clayton Rawson, Kody Garrett, Joshua Premo **b- Difficult Conversations, Real Biology: Student essentialist beliefs of race and biological sex** Josh Premo, Saskia Paepke-Chile, T. Heath Ogden, Jessica Cusick, & Brittney Wyatt, Utah Valley University	Beaumier Suite B-C
3:50 PM - 3:55PM Break	
3:55 PM - 4:55 PM Session D- Virtual sequential presentations (20-minutes) **MS Teams Link: 40 and 20 minute presentations** (Same link as session C) **a- Enhancing Student Engagement in College Biology: Leveraging Miro Virtual Whiteboards for Interactive Learning** Gaston Jofre-Rodriguez, Virginia Commonwealth University **b- Natural transformation of antibiotic resistance as a microbiology lab experiment** James F. Graves, University of Detroit Mercy **c- Is Tori seeing red? An activity to reveal the complexities hiding behind human pedigree charts.** Ahmad Mohammed Kamal, Si-ah Choi, Aoniya Colynn, Ashleigh Wood, Pamela Kalas University of British Columbia	Beaumier Suite B-C
4:55 PM - 5:00PM Break	

5:00 PM - 5:40PM Session E- Virtual Poster Presentations **MS Teams Link: Virtual Poster Presentations** **a- Enhancing Student Engagement in Biology Courses Using a Real-World Case Study** Dr. Dan Kiernan and Dr. Pearl Fernandes Division of Science, Mathematics, & Engineering, University of South Carolina, Sumter - A Palmetto College Campus **b- Collaborative Learning Environments: The dynamics that matter.** Connor Mackintosh, Zaira V. Meza-Leon, Brittney N. Wyatt, & Joshua Premo Utah Valley University **c- Leveraging Generative AI in Computational Biology Education** Camellia Moses Okpodu, University of Wyoming **d- Exploring Study Strategies in Introductory Biology Courses** Zaira V. Meza-Leon, Eden Backman, Molly Niswender, Jeremy L. Hsu, Joshua Premo, & Brittney N. Wyatt, Utah Valley University	Beaumier Suite B-C
5:40 PM - 6:00 PM Conference Conclusion and Closing Remarks **MS Teams Link: Closing Remarks**	Beaumier Suite B-C
6:00 PM - 7:00 or 7:30 PM Steering Committee Meeting (for committee members)	

ABSTRACTS BY CATEGORY

90-minute Workshop Presentations and Special Sessions

Exploring Natural Selection in Humans Using BioInteractive's Sickle Cell Resources - for your reference.
Jonelle Orridge and Nilo Marin, Broward College
Natural selection is often a challenging concept for students. This workshop will provide participants with impactful classroom resources and teaching strategies that enhance their ability to integrate natural selection into the teaching of evolution. Utilizing resources from HHMI BioInteractive, participants will engage as learners to identify and appreciate the significance of sickle cell disease in human populations and its application to biology concepts. There will be opportunities to identify how this phenomenon can be used to expand and elucidate the concept of natural selection. Participants will also explore and discuss teaching strategies to assist students in their comprehension of natural selection and evolution. This workshop will blend multimedia resources with hands-on learning activities to create an engaging and effective learning experience.

Investigating Climate Change through National and Local Case Studies with HHMI BioInteractive Resources
Tara Jo Holmberg, and Melissa Haswell HHMI BioInteractive
Curious about how to incorporate climate change into your course through active learning? This workshop will feature national and local case studies on impacts from, adaptations to, and mitigation of climate change, utilizing HHMI BioInteractive resources and traditional ecological knowledge (TEK). Participants will integrate real-world data, interactive tools, and TEK, to explore the complex dynamics of climate change across diverse geographical regions, combining empirical research with educational strategies to enhance climate science understanding among students. Case studies highlight various ecosystems and communities, offering insights into both universal and unique climate change challenges, as well as improved climate literacy, critical thinking, and proactive engagement outcomes in addressing environmental issues. This workshop underscores the importance of localized study within the global climate context, advocating for a holistic approach to climate education.

Models and Modeling: Tools of Engagement
Tim Herman, 3D Molecular Designs
The first challenge facing educators in the molecular biosciences is student engagement. How do we capture students' interest in the subject we are presenting? We have found that one answer to this question is the use of models and the process of modeling. Participants in this workshop will have a hands-on experience with several foundational models that have proven to be effective in capturing students' attention. Foundational models include:

- 3D-printed models of proteins… based on the atomic coordinates of solved protein structures.
- Interactive schematic models of proteins… that students can fold into 3D shapes following basic principles of chemistry
- A Dynamic DNA Discovery Kit… that can be constructed from its 3 basic components
- A Flow of Genetic Information Kit… that students can use to model the processes of DNA replication, RNA transcription and Protein Synthesis
- Cellular Landscapes of David Goodsell… that provide students with a unique view of the proteins in a cell as they carry out the molecular processes of life.

Participants will also be introduced to a series of recently developed Augmented Reality tools that enhance these physical models with overlayed information when viewed through a students' cellphone.

Morning Brew: An Intimate Discussion on Preparing For A Teaching Career Post-PhD
Facilitated By:
Nouran Amin, Assistant Teaching Professor of Biology at Ball State University,
JT Cornelius, a doctoral candidate at Indiana University School of Medicine
Deciding to pursue a teaching career after completing your PhD can be both exciting and challenging. Join us for a delightful breakfast session tailored specifically for graduate students considering a teaching career.
Whether you're just beginning to explore teaching opportunities or are actively preparing to apply, this session will serve as a safe space to connect with others who share your career aspirations and provide valuable insights into preparing yourself to transition from graduate school to a teaching role.
During the interactive session, we will offer practical guidance on navigating the academic job market, crafting compelling application materials, and preparing for interviews. The format will also include a Q&A segment where participants can ask questions and engage in meaningful dialogue about the realities of teaching careers in higher education.

20-minute Presentations
In- Person presentations
Friday, October 18th, 2024

Emphasizing the challenges of scientific communication using an icebreaker activity
Ashley Driver, University of Scranton
Effectively communicating scientific information is essential not only for advancing a specific field, but also 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 Cellular Biology course, I have found that 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 the party game Telestrations with increasingly technical biological terms. In this multi-round activity students are challenged to draw and communicate using limited 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 can result in humorous results that get students interacting early in the semester which helps break tension and promote an interactive learning environment.

Getting students to be "Wimpy Wimpy Wimpy:": Weekend Assignment for Key Concepts in an Anatomy and Physiology Course
Sarah Lovern, Concordia University of Wisconsin
In an effort to have students engage with the materials over the weekend instead of ignoring the class for several days, "Weekend Interaction with the Material Projects" (WIMPs) were implemented into an Anatomy and Physiology II course in the fall of 2023 and fall 2024. Students were given optional short videos to watch with bonus questions. These videos were often related to pop culture and limited to two minutes or less. Students then used the videos, class information, and additional research to answer the questions. Data was collected on student completion rate and answering correctly as well as a correlation with exam grades and final course grade. Additionally, a post-class survey was conducted to understand student perception of the WIMPs. Feedback was overwhelmingly positive. Students liked doing the assignment, diving deeper into the material, and that the assignments were optional. Some students disliked that the questions were challenging and would also forget to do them. Examples of the videos, questions, and the data will be presented.

U-RISE at MU’s Approach to Broadening Participation in Biomedical PhD programs and Research

Laurieann Klockow, Marquette University

The U-RISE at MU program, funded by the National Institutes of Health (NIH), aims to broaden participation in biomedical PhD programs and research by enhancing research training and professional development for underrepresented students in STEM disciplines. Implemented at Marquette University in 2021, the program adopts a comprehensive approach to equip students with the skills necessary for the successful attainment of a PhD and independent research careers. At its core, U-RISE offers a continuous two-year research experience under the guidance of research-active mentors trained in inclusive practices. The program's curriculum is multifaceted, incorporating hands-on laboratory experience, professional development workshops, a grant writing bootcamp, and a seminar course series to enhance the laboratory experience using a culturally validating curriculum. These elements work in tandem to foster critical thinking, problem-solving skills, and a strong sense of belonging among participants.

A key feature of U-RISE is its mentoring ecosystem, which establishes a network of support including faculty research mentors, professional development advisors, and graduate student peer mentors. This structure provides personalized guidance tailored to individuals at their unique stage of development. Because positive mentor-trainee relationships predict long-term success (Balster et al., 2010) the program emphasizes structured activities to enhance mentor-mentee relationships, including individual development plans and mentor-trainee contracts. To address the unique challenges faced by underrepresented students, U-RISE employs a culturally validating curriculum focusing on integrating cultural perspectives into the scientific discourse, promoting student confidence and sense of belonging. The program also recognizes the importance of family and social support, engaging scholars' families and friends through events like U-RISE Research Day. These interventions aim to increase persistence in STEM fields (Romero et al., 2020).

Early outcomes from Marquette's U-RISE program are promising. All students in the first cohort were admitted to competitive summer research programs and graduated within four years. Three out of four scholars continued to graduate school or NIH postbac programs (1 student chose to leave the program to pursue a biomedical career unrelated to PhD attainment). Participants reported improvements in confidence, research competency, and readiness for graduate-level education, as well as an increased sense of belonging and research self-efficacy.

The U-RISE program at Marquette University demonstrates a successful model for fostering diversity in the biomedical workforce, ensuring that underrepresented voices contribute meaningfully to scientific advancement.

Balster, N., Pfund, C., Rediske, R., & Branchaw, J. (2010). Entering Research: A Course That Creates Community and Structure for Beginning Undergraduate Researchers in the STEM Disciplines. *CBE Life Sciences Education*, *9*(2), 108–118. https://doi.org/10.1187/cbe.09-10-0073

Romero, D. R., Gonzalez, M., Clark-Ibanez, M., & D’Anna-Hernandez, K. (2020). A Culturally Validated Model of Student Success Services and Academic and Curriculum Enhancements at a Hispanic-Serving Institution. *Association of Mexican American Educators Journal*, *14*(3), Article 3. https://doi.org/10.24974/amae.14.3.401

Saturday, October 19th, 2024

Welcoming underrepresented minority undergraduate students into formal medical and scientific spaces

Emma Tillison, Medical College of Wisconsin

Abstract: The Medical College of Wisconsin (MCW) has many different pathway programs that engage underrepresented in medicine (URiM) students who are interested in pursuing medical or graduate school or other professional degrees. One such academic-year program at MCW is the Student Enrichment Program for Underrepresented Professions (StEP-UP) college program. As educators, the goal is to provide these students with many opportunities to connect with scientific or medical spaces for professional development. However, further exploration into how we can make the students feel welcome and give them a sense of belonging in these spaces once they are invited is required. In this presentation, we will describe the experiences of a graduate-level organizer and educator for StEP-UP, highlighting key sessions that received high praise from participants. Specifically, the presentation will describe one specific event where 10 pathway program undergraduate students were invited to MCW's 2023 Department of Medicine Research Retreat. Post-event feedback students in attendance will be discussed, using their perspectives to guide how MCW can provide more welcoming opportunities for URM students to enter into formal medical research spaces.

Midsemester feedback is an essential tool for a first-time teacher

Carrie Hetzel, Harvard University

Teaching as the sole instructor for a course for the first time can be extremely daunting. In Spring 2023, I had the opportunity to serve as an adjunct instructor in microbiology at Simmons University. Amongst the day to day of preparing lecture materials, developing assessments, and answering student emails, it was hard to know what I was doing well and what I could be improving. In this presentation, I will discuss how I collected, interpreted, and implemented student feedback through a mid-semester survey, and the describe the effects this had on the second half of my course. I hope this will serve as a guide both for other novice instructors that are teaching independently for the first time, and for more experienced mentor teachers who may be looking for new ways to help their mentees build confidence in their teaching.

Co-Teaching to bridge the gap between introductory-level and upper-division biology courses at a four-year institution

Takunda Maisva, Syracuse University

Students in postsecondary biology courses often expect to operate on the basis of rote memorization for a particular exam; rather than toward long-term understanding, critical analysis, synthesis, and application of content material. However, short-term memorization of facts about a concept does not equate to an applicable understanding. Moreover, biology departments and upper-division faculty often expect that introductory courses will establish foundational knowledge through higher-order thinking that students are expected to build upon in advanced courses. Students tend to compartmentalize information from introductory courses, struggling to recall or apply it in subsequent courses. Team-instruction, or Co-Teaching, is a teaching model that relies on multiple instructors to achieve the learning objectives for a given course. Through the literature, we see that co-teaching is associated with increased student engagement in the classroom, but the connection between increased engagement and student performance in courses is much less understood. To bridge contexts between introductory-level courses and upper-division courses, we **propose a co-**teaching model whereby the prerequisite content of upper-division courses is taught in introductory courses by the instructors who teach the follow-on courses to emphasize the connections between introductory and advanced courses. For this study, a faculty member who teaches the second-year genetics course at a large, private, research-intensive university in the Northeastern United States was taught the concepts in the introductory course that are considered foundational for learning in the genetics course, making sure to relate the introductory content to the upper-division course. We incorporated exam questions designed by the invited faculty member that would appear on their course's exams into the exam for the introductory course. Using a nonequivalent control-group design, we compared student performance in iterations of the introductory course with and without direct interaction with the upper-division faculty member. Quantitative analyses were complemented by qualitative surveys gauging student perceptions of the experience and potential impacts.

Virtual 20-minute Presentations

Enhancing Student Engagement in College Biology: Leveraging Miro Virtual Whiteboards for Interactive Learning

Gaston Jofre-Rodriguez, Virginia Commonwealth University

The integration of digital tools in education has transformed traditional teaching methods, enhancing student engagement and learning outcomes. Virtual whiteboards facilitate interactive collaboration among students, creating a more engaging learning environment. This presentation will explore the benefits of using Miro, a collaborative virtual whiteboard, in college-level biology courses. With its versatile interface and vast canvas, Miro supports interactive learning, enabling students to visualize complex biological processes, collaborate and engage in problem-solving activities, all done in real time. Through a practical demonstration I will share my experience of using Miro in a genetics course, showing the exercises I designed to deepen the understanding of independent assortment. Additionally, I will present survey results reflecting my students' perceptions of these activities. Moving forward, I aim to explore the impact of dynamic and visually enriched activities in Miro on the comprehension of intricate biological concepts.

Natural transformation of antibiotic resistance as a microbiology lab experiment

James F. Graves, University of Detroit Mercy

Transformation is a mechanism of gene transfer where plain donor DNA is taken up and used by a recipient cell. Artificial transformation of Escherichia coli bacteria is commonly performed in laboratory courses using cells treated with calcium chloride in the cold. Natural transformation is a life process and is observed in the gram-negative coccus known as Moraxella catarrhalis. This bacterium resides in the upper respiratory tract and can be associated with bronchitis, bronchopneumonia, sinusitis and otitis. The purpose of this work was to develop a natural transformation exercise that could be considered for use in a microbiology lab course for students interested in healthcare careers. It would assist in student learning about development and transfer of antibiotic resistance. Rifampicin is an antibiotic that reduces synthesis of RNA by interfering with DNA dependent RNA polymerase in bacteria. A spontaneous rifampicin resistant mutant of M. catarrhalis to be used as a donor was selected by incubating samples of antibiotic sensitive cells spread on brain heart infusion (BHI) agar containing rifampicin for a few days. Nucleic acid was isolated from cells of the mutant by a procedure using lysozyme, sodium dodecyl sulfate (SDS), protease, phenol, chloroform-isoamyl alcohol and ethanol precipitation. Cells for transformation (competent cells) were prepared by suspending a mass of freshly grown rifampicin sensitive cells in BHI containing magnesium chloride. Samples of cells incubated with nucleic acid, cells alone and nucleic acid alone were spread on respective agar plates, incubated for five hours and overlaid with melted agar containing rifampicin. After incubation, colonies were evident on plates containing cells that had been incubated with nucleic acid. Mutants and transformants were evaluated by staining, production of oxidase, fermentation reactions and testing of antibiotic resistance. An exercise on natural transformation in M. catarrhalis might offer some benefits in laboratory course education.

Is Tori seeing red? An activity to reveal the complexities hiding behind human pedigree charts.

Ahmad Mohammed Kamal, Si-ah Choi, Aoniya Colynn, Ashleigh Wood, Pamela Kalas
University of British Columbia

Pedigrees are common features of introductory genetics curricula, providing great opportunities for students to develop critical and analytical skills. However, they are usually presented with phenotypes entirely determined by genotypes, which does not reflect current-day understanding of genetics and can inadvertently reinforce genetic essentialist beliefs.

For example, red-green color vision deficiencies (CVDs), often used as examples to illustrate X-linked recessive inheritance patterns, are typically presented in a dichotomous way: either a family member has a red-green CVD, or they don't. However, red-green colour vision exists on a spectrum and is influenced by multiple factors. The diagnostic tools and "threshold values" used to diagnose red-green CVDs also vary across contexts and don't always hold biological significance.

To expose students to the nuances and intricacies hidden behind the black and white symbols used in pedigrees, we developed an in-class activity on protanopia (a form of red-green CVD) where the inheritance pattern does not fit an X-linked recessive model. Using information entirely inspired from published literature, students contend with real-life nuances such as the natural variation in red-green colour vision that exists across people, the validity and reliability of colour vision test results, and the difficulties associated with reducing a quantitative measure (level of red-green colour vision) into a dichotomous representation ("affected" vs. "unaffected").

We will present the activity, highlight some of the students' responses from its implementation with two different cohorts, and invite colleagues far and wide to provide us with feedback – and maybe try out the activity in their own classes!

40-minute Presentations

In-person Presentations

Friday, October 18th, 2024

A Walk in the Park: A Botanical Field Research Project for Biology Students.

Luciana Caporaletti, Penn State University

Beech trees are declining in number throughout the U.S. A contributing factor is Beech Tree Leaf Disease. Research has identified the pathogen, but continuous research on the spread and transmission of this disease is ongoing. My students and I conducted a survey of Beech trees that were symptomatic at two different Pennsylvania state parks; Promised Land State Park, and Francis Slocum. Our surveys were descriptive, however, there are multiple hypotheses that could be tested using this kind of research. This presentation will describe the trees, the disease, the methodology of our research, and our results. Suggestions for similar experiments will follow.

Exploring Math in Biology: Perspectives of Two-Year College Educators

Kristine Squillace Stenlund

University of Minnesota and Dakota County Technical College

Mathematics competency in the context of biology is important for STEM careers. Two-year colleges provide foundational science education to a large proportion of these developing professionals in the US and is an important arena for education research. This study employs a convenience survey was designed to explore 2-year college biology instructor perceptions and use of mathematics in the biology context addressing the following research questions:

(1) Do 2-year college instructors report using mathematics in biology classroom instruction?

(2)What are 2-year college instructor's perceptions of mathematics associated with biology classes?

(3) What are 2-year college instructor's perceptions of student understanding of mathematics associated with biology classes?

(4) What objectives do 2-year college instructors have for mathematics in biology classes?

(5) What activities do 2- year college instructors report when teaching mathematics in biology classes?

Respondents were asked a series of 6-point Likert questions surrounding efficacy, algorithmics, mathematical sensemaking, biological sensemaking, fixed mindset, and perceived difficulty in mathematical concepts pertaining to biological phenomena (RQ1-3). Mean values and standard deviations were calculated for each factor and statistically analysis through a paired t test and Cohen's d size effect. Questions 4 & 5 were addressed via ranking questions of learning objectives and classroom activities. Responses indicate instructors are confident with their mathematical abilities but do not feel the same confidence in their students. Data reveals that instructors do use mathematics in their biology classrooms and value the connection between content in their class learning objectives. Instructors report listing mathematical connections to biological phenomena as top learning objectives in their introductory biology classes. However, instructors also indicate they do not use classroom activities in line with these learning objectives. Overall, this study suggests 2-year college instructors may benefit from workshop opportunities focused on ways to allow students to build connections between mathematics and biology.

Saturday, October 19th, 2024

Morning Brew: An Intimate Discussion On Preparing For A Teaching Career Post-PhD

Facilitated By:
Nouran Amin, Assistant Teaching Professor of Biology at Ball State University,
JT Cornelius, a doctoral candidate at Indiana University School of Medicine

Deciding to pursue a teaching career after completing your PhD can be both exciting and challenging. Join us for a delightful breakfast session tailored specifically for graduate students considering a teaching career.

Whether you're just beginning to explore teaching opportunities or are actively preparing to apply, this session will serve as a safe space to connect with others who share your career aspirations and provide valuable insights into preparing yourself to transition from graduate school to a teaching role.

During the interactive session, we will offer practical guidance on navigating the academic job market, crafting compelling application materials, and preparing for interviews. The format will also include a Q&A segment where participants can ask questions and engage in meaningful dialogue about the realities of teaching careers in higher education.

Preparing Graduate Students for Teaching Through a Certificate in University Teaching Program

George Todd, University of Missouri-St. Louis

Many graduate students with career goals of teaching in higher education obtain teaching assistantships to gain teaching experience. However, many of these assistantships lack a structured foundation of teaching tools, pedagogies and observational feedback. The Certificate in University Teaching (CUT) program at the University of Missouri-St. Louis is designed to provide graduate students interested in teaching with tools, professional development and practice in the classroom. Here, I provide an overview of the CUT program, a personal reflection as a participant in the program, and space for discussions about how our respective institutions use or lack such programs for graduate students.

Virtual 40-minute Presentations

An Intriguing Intersectionality: The Role of Medical Experiences and First-Generation Status

Brittney N. Wyatt, Porter Bischoff, Clayton Rawson, Kody Garrett, Joshua Premo

It has been estimated ~1 in 2 individuals in the US suffer from a consistent medical condition (Raghupathi & Raghupathi, 2018). Yet limited research in science education has explored how students' medical experiences may impact their pursuits of science. The current study examined the relationships between student (n = 366) medical experiences and indicators of science success (e.g. science motivation, immersion, and integration) for students taking biology classes at a public teaching-focused university. Results show students with a medical experience had significantly higher values, yet small magnitude, in indicators of success. Subsequent analysis showed the quality of medical experience was correlated with many indicators of success; particularly if the experience resulted in more engagement with science. Examinations of intersectionality between medical experiences and underrepresented student status highlighted first-generation students (FGS) with medical experiences to have the highest averages in science motivation, immersion, and integration. This is surprising given FGS almost always have lower values than their peers in prior studies. When examining the data for a potential mechanism of action, stronger associations between the quality of FGS medical experience and their indicators of success were found. Thus, while medical experiences may promote more success for all students in science, it may have a uniquely important role for FGS. Implications of these results for student success in science will be discussed.

Difficult Conversations, Real Biology: Student essentialist beliefs of race and biological sex

Josh Premo, Saskia Paepke-Chile, T. Heath Ogden, Jessica Cusick, & Brittney Wyatt, Utah Valley University

Educators must support students' willingness to be inclusive in their beliefs as this has been found to be critical for creativity and productivity in their future career. Endorsing essentialist ideas (e.g. all males are the same) can sometimes combat inclusive ideas (e.g. biological sex is a spectrum). The current study examined students' (n = 876) essentialist beliefs of race and biological sex to answer the following research questions: 1) What essentialist views regarding racial genetics and biological sex do students begin and end the semester with? 2) What factors predict students' final endorsement of non-essentialist ideas? 3) If students recognize their essentialist ideas are changing, why do they believe these have changed? Results showed that students were 2.5 times more likely to embrace essentialist ideas of biological sex than race. Factors that predicted non-essentialism in both areas included: 1) engagement in active learning, 2) less time listening to lectures, 3) liberalism, and 4) instructor addressing the topic in class. A unique factor predicting non-essentialist ideas of race was student connection to their instructor. At the end of the semester 38% of students felt that they were more accepting of non-essentialist ideas of race and 29% were more accepting of biological sex as a spectrum. In both cases, most students felt that evidence from class was the biggest contributor to the change, while having previously misunderstandings was the smallest. How these results can inform instructional practices seeking to increase student inclusivity in beliefs will be discussed.

Poster Presentations

In- Person Presentation

Effects of student demographics on self-identity as a scientist in course-based research modules

Christopher Yahnke, University of Wisconsin - Stevens Point

Course-based Undergraduate Research Experiences (CUREs) are an ideal teaching method to share the benefits of authentic research experiences to a larger, more diverse population of students. We created a national network of field-based, mammalogy focused CURE modules investigating the behavioral ecology of squirrels, called Squirrel-Net. Previously, we found that Squirrel-Net improves student self-identity as scientists. Here, we describe the demographic parameters of Squirrel-Net students and their impact on students' likelihood to self-identify as scientists. Students from almost 60 institutions spanning 90 courses responded to surveys before and after participating in a Squirrel-Net CURE between 2019-2022. Student demographics included gender, ethnicity, identification as Hispanic, and first-generation status. Student respondents for pre- and post-CURE surveys (N = 2382) were very demographically similar, with students most often identifying as female, white, non-Hispanic, and non-first-generation. We analyzed demographic parameters as predictors of self-identity as scientists with paired response data (N=466) using GLMs in R. Females and non-first-generation students were more likely to identify as scientists after participating in Squirrel-Net. Females were also more likely to change their response in a positive direction than males, and first-generation students were less likely to change their response than non-first-generation students. Our analyses provide a demographic snapshot of Squirrel-Net students, highlight the importance of expanding and diversifying the network, and confirm the benefits and pedagogical effectiveness of Squirrel-Net for undergraduate students.

Leveraging the Benefits of the Digital Era: Identifying the value of Non-Traditional Learning Methods

Brooke Greiner, Medical College of Wisconsin

The most optimal learning style varies between individuals. Living in the Digital Era, we have the ability to present educational information in many different forms. Utilization of more non-traditional learning methods, such as YouTube or Podcasts, as a form of scientific education benefits both classroom learning and the dissemination of scientific information to the general public. However, presenting scientific information in non-traditional formats is not common practice. We distributed a survey to the general adult population which aimed to assess the value of non-traditional learning methods for learning topics related to science, technology, engineering, and math both in and outside the classroom. We evaluated the general desire for more non-traditional learning methods and identified what forms of non-traditional learning methods may be most useful for learning in and outside of the classroom. We identified similarities and differences in responses between groups based on age, gender, level of education, and involvement in a STEM based career. Understanding the desire for non-traditional learning methods would highlight the need for educators and researchers to work together to diversify the scientific content that currently exists. By identifying preferred methods of non-traditional learning across different groups within the population, there is potential for platform and audience specific training for educators and researchers which will minimize time being spent learning less utilized platforms.

Incorporating Conversations on Diversity, Equity, and Inclusion into the Undergraduate Research Experience

Ellie Marino & Stacia Peiffer, Marquette University, Milwaukee, WI

Though diversity, equity, and inclusion (DEI) has garnered significant attention in the STEM community over the last decade, formal guidance and programming to facilitate DEI conversations at the undergraduate level remains limited. To incorporate intentional communication about diversity, equity, and inclusion, a small but impactful change was made to the traditional Summer Research Program (SRP) curriculum in the Biological Sciences Department at Marquette University. While previous curricula have featured “journal club” meetings centered around a scientific manuscript relevant to a specific biological field, the program instead prompted students to present a paper and facilitate a discussion regarding a DEI issue in science. Throughout the nine-week program, students facilitated three journal clubs, where paper topics included inclusive scientific language, the sex and gender gap in scientific publications, and methods of supporting inclusive and accessible science communication. Student feedback on this journal club style was overwhelmingly positive, and class discussions were both comprehensive and productive. Though the Summer Research Program is primarily designed to facilitate undergraduate research, the journal clubs were a simple and effective method of integrating intentional conversations about the intersection of DEI and science. Importantly, this activity demonstrates that diversity, equity, and inclusion can be seamlessly incorporated into the undergraduate research experience and is a critical educational opportunity in building undergraduate scientists.

Enhancing Belonging for Underrepresented Students through Student-Designed Learning Field Experiences

Brian R. Shmaefsky, Lone Star College – Kingwood

This study explores the effectiveness of teaching the scientific method through student-driven observational studies of local wildlife behavior in an introductory environmental science course for college freshmen. By integrating place-based instruction with core field science principles, students gained hands-on experience in hypothesis formation, data collection, and analysis, while also developing a deeper connection to their local ecosystem. This project uses urban squirrels as a model fro observing wildlife behaviors such as feeding, movement, and social interactions in nearby natural areas. Through structured assignments and guided inquiry, students learn to apply the scientific method in a real-world context, fostering critical thinking and environmental awareness. Preliminary results suggest that this approach enhances engagement, improves understanding of scientific processes, and encourages active learning. Additionally, the proximity of the study site allows for continuous observation and data gathering, offering a dynamic learning environment that bridges classroom theory with practical experience in ecology and environmental science.

Virtual Poster presentations

Enhancing Student Engagement in Biology Courses Using a Real-World Case Study

Dr. Dan Kiernan and Dr. Pearl Fernandes
Division of Science, Mathematics, & Engineering, University of South Carolina, Sumter - A Palmetto College Campus

In recent years there has been an emphasis on a case study approach to teaching science courses. This pedagogical method has shown great promise in enhancing the understanding of concepts in the science classroom. Case studies lay the groundwork for inquiry-based units that help students enhance teamwork, deductive reasoning and provide training to improve their critical thinking.

Students in a Biology course for non-majors were provided a case study of a male African American high school senior football player who collapsed during practice and was observed to be not breathing and had no pulse. There was no prior history of medical problems. Students were also provided with the results of the blood test. Students were divided into four groups and were asked to:

1) Research, formulate and find a cause for the athlete's collapse.
2) Research the effects of genetic disorders and their interactions in cause of the collapse.
3) The effect of genetic disorders on organs and organ systems.
4) The effects at the cellular level.

The student groups presented their results and our observations and findings indicated that student learning was enhanced through this relevant case study and helped them make connections between concepts and real-world problems. A student quote from the course regarding the case study, "this should be a regular activity in classrooms. Very entertaining and educational."

Collaborative Learning Environments: The dynamics that matter.

Connor Mackintosh, Zaira V. Meza-Leon, Brittney N. Wyatt, & Joshua Premo
Utah Valley University

Common active learning strategies include the use of group work with the assumption that group work will increase student learning. However, there is inconsistency in how much students will learn in their group. Some may learn more than others due to a variety of factors such as: interactions, contributions, and willingness to work with each other in a group (Premo, Wyatt, et al., 2022). The current study expands on research in this area by looking at how different dynamics predict both immediate (assessed at the end of each activity) and long-term (exams and end of semester) achievement by answering the following questions: 1) What group dynamics predict an increase in learning (immediate and long-term)? 2) What factors drive students to engage in beneficial group dynamics? We collected peer ratings of group dynamics from over 200 students enrolled in undergraduate biology courses. The results indicate significant correlations between group dynamics and both immediate and long-term learning outcomes, (except for final exam scores). Students achieved higher end of activity scores when group dynamics included more content contributions, general interactions, monitoring of on-task behavior, motivation to produce quality work, and when members were perceived as having higher knowledge, skills, and abilities ($p < 0.05$). Additionally, students attained higher end-of-semester scores when their group members expressed a desire to work with them, liked them, and enjoyed spending time with them in class ($p < 0.05$). The study also reveals demographic factors influencing group dynamics. For example, women were rated higher than men in social connection, contribution, interaction, and keeping the team on track but not in knowledge dynamics. Furthermore, students were more connected to group members who identified as as having higher socioeconomic status growing up. The dynamics of contributions, interactions, keeping the team on track, and social connection followed a similar pattern. These findings underscore the importance of student behavior within groups, the group's social environment, and peer support in optimizing undergraduate science learning. They also highlight how gender and socioeconomic status can impact student engagement in groups.

Leveraging Generative AI in Computational Biology Education

Camellia Moses Okpodu, University of Wyoming

Generative Artificial Intelligence (AI) tools have emerged as powerful aids across scientific domains, including Computational Biology. In this abstract, I share my experiences of integrating these tools into teaching a computational biology course—a field that increasingly intersects with computational science, particularly within the biological sciences. Computational biology bridges molecular biology and computers, enabling data-driven insights into biological systems. Historically, the discipline relied heavily on handcrafted algorithms for protein, gene, and nucleic acid analysis. The advent of Generative AI, exemplified by models like GPT-3, has transformed how we approach computational biology education. Generative AI assists educators in refining course materials, creating engaging content, and improving scientific communication. Finding specific code snippets for teaching and learning, such as using R-Studio, becomes more efficient. AI-generated exercises challenge students and promote critical thinking. Additionally, Generative AI can create custom cartoon images for presentations, enhancing visual communication. While embracing AI, it's crucial to discuss the ethical, legal, and social implications with students. Encourage responsible use and awareness of biases inherent in AI-generated content. Generative AI empowers educators and learners in computational biology. By leveraging these tools, we enhance teaching effectiveness, foster creativity, and prepare students for an AI-augmented scientific landscape.

Exploring Study Strategies in Introductory Biology Courses

Zaira V. Meza-Leon, Eden Backman, Molly Niswender, Jeremy L. Hsu, Joshua Premo, & Brittney N. Wyatt , Utah Valley University

Effective study strategies are crucial for student success in STEM disciplines, yet there is limited research on the factors that influence the adoption and adaptation of these strategies throughout a semester. This study explores two key questions: 1) What factors drive changes in study strategies among students in introductory biology courses? 2) How do these study strategies evolve over time? To answer these questions, we administered a study strategies survey at the beginning and end of the semester in introductory biology courses at a private comprehensive university in California and a public open-enrollment university in Utah. Our findings indicate that students adopt and modify their study strategies during the semester, with instructors serving as the primary source of new strategies. Also, strategies involving trial and error, as well as vicarious and mastery experiences, show significant changes over the semester, while textbook reading declines by nearly 20% by the end of the semester. There was also significant variability in study strategies between institutions. These results suggest that instructor guidance plays a crucial role in fostering critical thinking and encouraging the adoption of more effective study practices. Overall, students actively refine their study strategies throughout the semester, but this may vary significantly. What results indicate about student's studying habits and how instructors might optimize studying in service of greater learning will be discussed.

ACUBE 2024 ATTENDEE CONTACT INFORMATION

Habeeb Rahman Acharathparakkat
Marquette University
Milwaukee, WI
Habeebrahman.acharathparakkat@marquette.edu

Leonard Asare
Medical College of Wisconsin
Milwaukee, WI
lasare@mcw.edu

Nouran Amin
Ball State University
Muncie, IN
nouran.amin@bsu.edu

Celina Bellanceau
University of Tampa
Tampa, FL
cbellanceau@ut.edu

Suzanne Bessette
Northwestern Michigan College
Traverse City, MI
sbessette@nmc.edu

Mary Bonine
College of Lake County
Grayslake, IL
mary.bonine@gmail.com

Rebecca Burton
Alverno College
Milwaukee, WI
rebecca.burton@alverno.edu

Maleen Cabe
Elgin Community College
Elgin, IL
mcabe@elgin.edu

Luciana Caporaletti
Penn State University
Dallas, PA
lovethewildearth@gmail.com
kxc112@psu.edu

Alison Clark
adoyclark@gmail.com

Jonathon Cohen
Kankakee Community College
Kankakee, IL
Jcohen@kcc.edu

JT Cornelius
Indiana University School of Medicine
Bloomington, IN
jycornel@iu.edu

Stephen Daggett
Avila University
Kansas City, MO
Stephen.daggett@avila.edu

Elizabeth DiCesare
Rochester Institute of Technology (RIT)
Rochester, NY
ewdsbi@rit.edu

Ashley Driver
University of Scranton
Scranton, PA
ashley.driver@scranton.edu

Pearl Fernandes
University of South Carolina Sumter
Sumter, SC,
pefernan@mailbox.sc.edu

Elaine Grafelman
Marquette University
Milwaukee, WI
elaine.grafelman@marquette.edu

James Graves
University of Detroit Mercy
Detroit, MI
gravesjf@udmercy.edu

Monica Graziani
Franklin Regional School
mgraziani@franklinregional.k12.pa.us

Brooke Greiner
Medical College of Wisconsin
Milwaukee, WI
bgreiner@mcw.edu

Melissa Haswell
Davenport University
Midland, MI 48640
mhaswell@davenport.edu

Neil Haave
University of Alberta
Alberta, Canada
nhaave@ualberta.ca

Carrie Hetzel
Harvard University
Boston, MA
carriehetzel@g.harvard.edu

Tim Herman
MSOE Center for BioMolecular Modeling
Milwaukee, WI
herman@msoe.edu

Tara Holmberg
HHMI BioInteractive
Frederick, MD
holmbergt@hhmi.org

Hamidah Idris
University Pendidikan Sultan Idris
Perak, Malaysia
Hamidah.idris@fsmt.upsi.edu

Gaston Jofre-Rodriguez
Virginia Commonwealth University
Richmond, VA
jofrerodrig@vcu.edu

Pamela Kalas
University of British Columbia
Vancouver, Canada
pamelakalas@gmail.com
Andrew Karls
Lakeland University
Plymouth, WI
karlsA@lakeland.edu

Dan Kiernan
University of South Carolina Sumter
Sumter, SC
kiernand@uscsumter.edu

Laurieann Klockow
Marquette University
Milwaukee, WI 53233
laurieann.klockow@mu.edu

Nadine Kriska
University of Wisconsin-Whitewater
Whitewater, WI
kriskan@uww.edu

Mark Lasek
Clifton Park, NY
bvab72@gmail.com

Grace Lee
College of DuPage
Glen Ellyn, IL
leeg3223@cod.edu

Sukanya Lodh
Marquette University
Milwaukee, WI
sukanya.lodh@gmail.com

Sarah Lovern
Concordia University of Wisconsin
Mequon, WI
sarah.lovern@cuw.edu

Ken Mager
Kankakee Community College
Kankakee, IL
kmager@kcc.edu

Takunda Maisva
Syracuse University
Syracuse, NY
tmaisva@syr.edu
Gigi (Khadijah) Makky
Marquette University
Milwaukee, WI
khadijah.makky@marquette.edu

Judith Maloney
Marquette University
Milwaukee, WI
judith.maloney@marquette.edu

Gabriella Marino
Marquette University
Milwaukee, WI
gabriella.marino@marquette.edu

Selinda Martinez
Laredo Community College
Laredo, TX
selinda.martinez@laredo.edu

Anne McIntosh
University of Alberta
Alberta, Canada
amcintos@ualberta.ca

Daniel Meer
Marquette University
Milwaukee, WI
Daniel.meer@marquette.edu

Kayla Miller
Burnsville, MN
okaylamay@gmail.com

Gwen Miller
Collin College
McKinney, TX
gcmiller@collin.edu

Michelle Mynlieff
Marquette University
Milwaukee, WI
Michelle.mynlieff@marquette.edu

Michele Morris
HudsonAlpha Institution for Biotechnology
mmorris@hudsonalpha.org

Rita Okeke
Marquette University
Milwaukee, WI
Rita.okeke@marquette.edu

Camellia Okpodu
University of Wyoming
Laramie, WY
cokpodu@uwyo.edu

Paul Pickhardt
Lakeland University
Plymouth, WI
pickhardtp@lakeland.edu

Josh Premo
Utah Valley University
Orem, UT
jpremo@uvu.edu

Tara Prestholdt
University of Portland
Portland, OR
holdt@up.edu

Wan Zugainis Saad
University Putra Malaysia
Seri Kembangan, Malaysia
zuhainis@upm.edu.my

Liz Scott
Kankakee Community College
Kankakee, IL
escott@kcc.edu

Madhavi Shah
Raritan Valley Community College
Branchburg, NJ
madhavi.shah@raritanval.edu

Rose Sheykhani
Lakeland Community College
Kirtland, Oh
Rsheykhani1@lakelandcc.edu

Brian Shmaefsky
Lone Star College – Kingwood
Kingwood, TX
brian.r.shmaefsky@lonestar.edu

Scott Shreve
Miami University
Oxford, OH
shrevesm@miamioh.edu

Aditi Sinha
Loras College
Dubuque, IA
Aditi.sinha@loras.edu

Denise Slayback-Barry
Indiana University
Indianapolis, IN
dlslayba@iu.edu

Greg Smith
Lakeland University
Plymouth, WI
smithgr@lakeland.edu

Kristine Squillace- Stenlund
Dakota County Technical College
Rosemount, MN
ksquisten@gmail.com

Ning Sui
NC State University
Raleigh, NC
nsui@ncsu.edu

Lynn Swafford
Wayne Community College
Farmville, NC
alswafford@waynecc.edu

Bhim Thapa
Marquette University
Milwaukee, WI
Bhimsen.thapa@marquette.edu

Aeisha Thomas
Crown College
Saint Bonifacius, MN
Thomasa@crown.edu

Emma Tillison
Medical College of Wisconsin
Milwaukee, WI
etillison@mcw.edu

George Todd
University of Missouri-St. Louis
St Louis, MO
gtodd576@aol.com

Andrea Turcu
University of Louisiana
Lafayette, LA
Andrea.turcu1@louisiana.edu

Danielle Twaroski
North Hennepin Community College
Brooklyn Park, MN
danielle.twaroski@nhcc.edu

Mark Vanden Avond
Medical College of Wisconsin
Milwaukee, WI
mvandenavond@mcw.edu

Susan Wadkowski
Lakeland Community College
Kirtland, Oh
swadkowski@lakeland.edu

Jason Wiles
Syracuse University
107 College Place
Syracuse, NY
jwiles01@syr.edu

Daniela Wright
Medical College of Wisconsin
Milwaukee, WI
duwright@mcw.edu

Britt Wyatt
Utah Valley University
Orem, UT
Britt.Wyatt@uvu.edu
Christopher Yahnke
University of Wisconsin- Stevens Point
Auburndale, WI
cyahnke@uwsp.edu

Michelle Yingling
University of Dayton
Dayton, OH
Myingling1@udayton.edu

Robert Yost
Indiana University Indianapolis
723 W. Michigan St., SL378
Indianapolis, IN
ryost@iupui.edu

***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 past 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 for articles described above.

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) or their manuscript will not 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 either as a Microsoft Word or RTF (Rich Text 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. Charges will be the membership fee at the time of submission per page. Once the authors' membership or page charge status has been cleared, the manuscripts will be sent to two anonymous reviewers as coordinated through the Editorial Board. Reviewer names and affiliation will be withheld from the authors. The associate editors will examine the article for compliance with the 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 compliance is met or the page cost conditions 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 reviewers. 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 acceptance. Revisions and resubmission should be made within six months. Manuscripts resubmitted beyond the six-month window will be treated as a new submission. Should manuscripts requiring revision be resubmitted without corrections, the 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.

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.