Connecting interdisciplinary research and place-based learning: Using a local ecosystem as the focus for an undergraduate research group

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Abstract: Undergraduate research experiences benefit students' scientific skills, and recent trends in undergraduate research and education include focusing on interdisciplinary projects and on place-based learning. Here we describe a semester-long pilot interdisciplinary undergraduate research program focused on local aquatic ecosystems, discuss perceived benefits of this research approach, and show how this program's structure could be modified for use at other undergraduate institutions. The program included nine undergraduate students and five faculty from multiple scientific disciplines (geography, virology, ecology, vertebrate and invertebrate zoology) and involved approximately half a day of research per student per week and weekly hour-long lab meetings of the entire group, followed by end-of-semester poster presentations to the university. Student self-assessment data indicated that the program improved students' perceptions of their scientific ability, as well as their comfort level at performing scientific skills. We suggest that bringing together faculty from multiple disciplines with projects focused on the same local ecosystem is a valuable technique for providing undergraduate students with not only hands-on research experience, but also with (1) exposure to a diversity of research areas and methods and (2) a better understanding of the ecosystems in and around their campus.

Introduction

Research experiences for undergraduate students have been shown to have many benefits, including increasing the likelihood of students pursuing STEM graduate degrees (Eagan et al. 2013). Among students that choose to attend graduate school, those that participated in research experiences as an undergraduate possessed stronger research skills than those that have no undergraduate research experience (Gilmore et al. 2015). A survey of undergraduates participating in research at liberal arts colleges showed that 91% of students reported professional and/or personal gains from their experience (Seymour et al. 2004), and Lopatto (2004) found similar positive results in a larger survey of >1100 undergraduate researchers. Most participating students appreciate the benefits of research experiences.

In the past two decades, some research experiences for undergraduates have shifted from a single-discipline focus to an interdisciplinary approach, which helps to prepare students for the interdisciplinarity inherent in many STEM careers and can increase diversity in research applicant pools (Raicu and Furst 2009). Another recent emphasis in some STEM disciplines has been a focus on place-based science teaching, defined by Semken and Freeman (2008) as a style of teaching that "focuses on local and regional environments and synthesizes different ways of knowing them." Place-based education may increase diversity in educational programs (Semken 2005) and increase both the students' academic performance and feeling of belonging (Johnson et al. 2020).

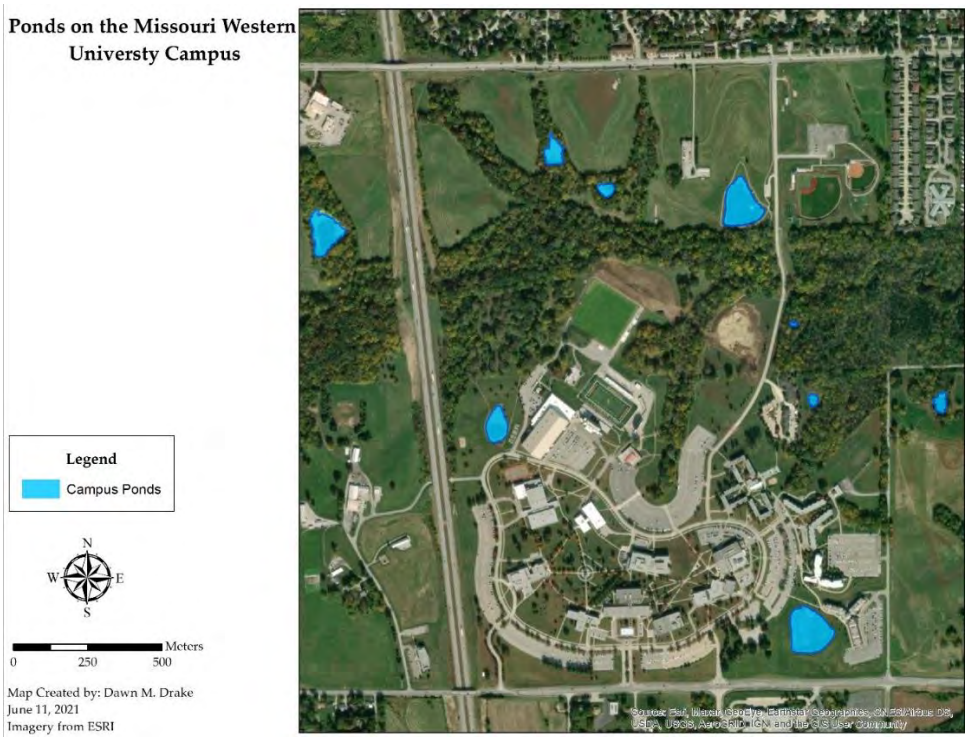
Some recent undergraduate research experiences have focused on combining an interdisciplinary approach with place-based learning (e.g., Montgomery 2020). Here we describe our development of a pilot interdisciplinary semester-long undergraduate research program focused on a specific local ecosystem, the Missouri Western State University campus ponds. Some faculty in the MWSU biology department have conducted research in the campus ponds for years, while others began pond-focused projects in the 2020-2021 academic year, and we determined that working together as a research group would allow us to address larger questions than our individual labs could address. The goal of this collaborative project was to begin to address the question "What biotic and/or abiotic factors drive diversity in these campus ponds?" The desired outcomes were (1) to provide students with a hands-on research experience focused on a piece of the group's overarching research question, (2) to give students the experience of participating in a collaborative, interdisciplinary research group with weekly lab meetings, and (3) formal student presentations of their research results in a poster symposium at the end of the semester.

Procedure

The large 740-acre (300-ha) Missouri Western State University campus, located in St. Joseph, includes nine former farm ponds with a range of sizes (0.05-0.97 ha), depths (0.65-2.2 m mean depth), and watershed characteristics; four ponds are in areas that receive heavy human use – e.g., in the middle of campus or beside roads/sidewalks – and five are in more remote wooded areas (Figure 1). These ponds provide an on-campus "natural laboratory" ideal for research projects from diverse disciplines.

Five faculty from different scientific disciplines (geography, virology, herpetology, ichthyology, and invertebrate zoology) led pond-focused research projects with the overarching research question of "How does watershed land use affect the biota of urban ponds?" We advertised for undergraduate research students via the Biology Department's Program of Research, Teaching, and Applied Learning (PORTAL) website, posters advertising the research interests of faculty, a department email listserv, announcements in geography classes, and a Powerpoint slide shown in freshman- and sophomore-level majors biology classes at the beginning of the semester. Nine students signed up to work with individual faculty on project topics including aquatic turtle population ecology, isolation of viral DNA from pond water, developing DNA markers for fish species identification, zooplankton population dynamics, and using GIS to map the ponds and their watersheds. Each faculty-student team determined their own research schedule and goals, which varied from developing new laboratory protocols to learning to use specific GIS and GPS applications, to directly testing hypotheses by collecting data in the field. In some cases, students helped to develop the initial project goal(s); in other cases, the faculty member had already selected a goal, but encouraged the student(s) to help determine how to address the goal.

Figure 1. Ponds on the Missouri Western University Campus.



Weekly lab meetings of the "Pond Team" students and faculty lasted 45-60 minutes. During the initial meeting, all members introduced themselves, learning objectives (Table 1) were explained, and the group toured four of the more accessible ponds to learn about their history and ecology from a faculty member. Subsequent meetings were organized, in rotation, by participating faculty labs and provided opportunities for students to present their project ideas and/or preliminary data to the group and for faculty to briefly introduce the group to their areas of expertise (which was eye-opening for students, as well as other faculty). Meetings also offered an opportunity for a brief weekly report from each student on challenges faced and progress made during the preceding week. Near the end of the semester, one lab meeting was devoted to a discussion of how to construct a conference-style scientific poster and prepare an "elevator speech" to go with it. In the last week of the semester, students' posters were presented to the rest of the university and community as part of a formal PORTAL undergraduate research symposium.

Development of this research program format was facilitated by our institution's transition to a four-class-days-per-week schedule that leaves Fridays open for applied learning. However, a similar format could fit within a more typical five-class-day-per-week schedule, as long as a set weekly lab meeting time could be established for the entire group and individual student/faculty groups could set aside time dedicated to research.

The program described here took place during the spring semester (January-May) but could be carried out during any semester, although fieldwork for some projects (e.g., trapping turtles) cannot feasibly occur during winter. Several individual faculty continued their pond-focused fieldwork over the summer, and this program will also be conducted in the fall semester.

Assessment

We requested that students complete a pre- and post-program self-evaluation of their comfort level in performing scientific skills as well as a post-program SALG URSSA (validated) assessment of their perceived gains during the program (available at salgsite.net/instrument/92544). Surveys were anonymous except for identifying codes used on the self-evaluations to ensure that students' pre- and post-program responses could be matched; one faculty member assigned the codes to individual students, and another faculty member handled the survey data.

Eight students completed the SALG URSSA assessment. Students perceived that they had experienced moderate to good gains in skills related to the program's learning objectives over the course of the semester, as indicated by a selection of responses to SALG URSSA questions (Table 2).

While there is high overlap in standard deviations for mean response scores, the two highest means suggest that students perceived great improvement in their ability to explain their research to others and in their understanding of what everyday research is like. Student responses also showed that the program had favorably impacted their attitudes toward research: they felt that they had engaged in real-world research and felt like scientists who were responsible for their own work, were able to think creatively about their projects, and were part of a scientific community (Table 3). Finally, open-ended responses indicated that students were positively impacted not only by the research experience, but also by the weekly interdisciplinary lab meetings (Table 4).

Table 1. Major learning objectives for the MWSU Pond Team.

Identify a gap in knowledge in their area of research
Develop a research question
Formulate hypotheses
Identify and demonstrate the ability to use appropriate research methods
Troubleshoot research methods
Work collaboratively with others
Work autonomously
Understand work in the diverse areas of the Pond Biodiversity Project and describe how their own projects fits in
Communicate effectively to explain their research project to (1) other people working on the Pond Biodiversity Project and (2) people who are not working on this project
Reflect on their research to identify strengths and opportunities for improvement

Table 2. Selected SALG URSSA scores for student self-evaluation of perceived gains in scientific skills (1=no gain, 2=a little gain, 3=moderate gain, 4=good gain, 5=great gain).

Scientific skill	Mean score (±SD)
Formulating a research question that could be answered with data	3.9 ± 0.8
Figuring out the next step in a research project	4.2 ± 0.5
Understanding the theory and concepts guiding my research project	4.1 ± 0.6
Identifying limitations in research methods and designs	4.1 ± 0.8
Conducting observations in the lab or field	4.2 ± 0.7
Comfort in working collaboratively with others	4.2 ± 0.9
Ability to work independently	4.1 ± 1.0
Understanding the connections among scientific disciplines	4.2 ± 0.7
Explaining my project to people outside my field	4.5 ± 0.5
Confidence in my ability to contribute to science	4.1 ± 0.6
Understanding what everyday research work is like	4.5 ± 0.8

Table 3. Selected SALG URSSA scores for student self-evaluation of extent of engagement in attitudes and behaviors (1=none, 2=a little, 3=some, 4=a fair amount, 5=a great deal).

Activity	Mean score (±SD)
Engage in real-world research	4.6 ± 0.5
Feel like a scientist	4.6 ± 0.5
Think creatively about the project	4.0 ± 0.5
Feel responsible for the project	4.5 ± 0.5
Feel a part of a scientific community	3.9 ± 0.8

Table 4. Selected SALG URSSA student comments.

I enjoyed meeting every week and being part of a team.
I think that this group meeting with multiple disciplines was a big step forward.
It really helped me to understand what it would be like to work hands on.
It promoted my interest in working with animals and studying in labs and conducting research to better understand our environment.
I just gained a lot of field experience and leadership skills.
I am very likely to enroll in a graduate program after doing these multiple research projects.

Discussion

The key points of our semester-long research program were (1) a research focus on an easily accessible local ecosystem, (2) a broad overarching project topic/research question that allows participation of faculty and students from multiple scientific disciplines, (3) hands-on research experience for undergraduates, (4) regular lab meetings that familiarize students with their colleagues' work and allow students to update the group on their own work, and (5) formal public presentation of research results by individual students that allows them to practice professional skills. These key points resulted in student perceived benefits, such as improved scientific skills and attitude towards research. By applying these key

points, this research program's structure could be modified for use at other undergraduate institutions.

Focusing on an easily accessible local ecosystem, as was done here with the Missouri Western State University campus ponds, could be readily modified for use at other undergraduate institutions. Place-based education can provide important benefits such as increasing diversity in educational programs (Semken 2005) and students' academic performance and feeling of belonging, as was seen in a place-based learning program for freshmen (Johnson et al. 2020). The size of the group could also be scaled to meet the needs of the institution. In our program the overall student: faculty ratio was 1.8 (nine students, five faculty), but individual faculty mentored one to five students, modifying their project plans based on the number of interested students. A higher student:faculty ratio in a program like this could be workable as long as projects are feasible for groups of students; for example, sampling water chemistry, macroinvertebrates, and turtles are research activities conducive to teams of students working together to collect data. Other teams could have small groups of students working on interrelated parts of the project. For instance, with the geography students, one group focused on mapping the ponds while another was completing a literature review in preparation for the next step in the watershed mapping portion of the project.

Having a broad overarching program goal that allows for the participation of faculty and students from multiple scientific disciplines, reinforced by regular lab meetings, provides important exposure for students to a diversity of research areas and methods. This certainly contributed to the students' perceived gains in scientific skills (their ability to explain their research to others and understanding what everyday research is like) and attitude towards research (engaging in real-world research, feeling like a scientist, feeling responsible for the project, and feeling a part of a scientific community). The application of an interdisciplinary approach for undergraduate research experiences helps to prepare students for the collaborative nature of many STEM careers and can increase diversity in research applicant pools (Raicu and Furst 2009). This year's Pond Team research group was a pilot program, and student comments and evaluations (both formal and informal), coupled with faculty experience, have given us indications of how this program can be modified in future semesters. Student evaluations were overwhelmingly positive, but a few metrics on the self-evaluation - for example, skill in data analysis - received lower scores, suggesting that these aspects could be more heavily emphasized in future semesters, to the extent possible for individual projects (some are more focused on development of methodology). Faculty were pleased to have an opportunity to learn more about their colleagues' research and to provide and receive feedback from peers in slightly (sometimes very) different areas of expertise. In addition to the benefits to personal research for the faculty, many of us feel better, prepared to discuss the different areas of research within the department with prospective students and their parents.

We feel that this pilot program was a success, and we plan to continue with the interdisciplinary Pond Team in the future. Plans for the upcoming year(s) include continuing with the research that was already started, moving into new areas, and inviting new disciplines. For example, we have added a geologist and feel the addition of a mathematician and/or statistician would also be helpful. This project has also served as a model for the developing an additional interdisciplinary, place-based team centered around a long-term on-campus prairie restoration project on 40 acres of former hay fields.

The typical undergraduate research experience was enhanced here by the application of an interdisciplinary approach and place-based learning, to create a program that demonstrated notable student perceived gains. In addition to facilitating hands-on research experience for undergraduates, this type of program results in public presentations by the students. Both of these have well-acknowledged benefits, such as increasing the likelihood of students pursuing STEM graduate degrees (Eagan et al. 2013) and students possessing stronger research skills (Gilmore et al. 2015). Most participating students appreciate the benefits of research experiences (Lopatto 2004 and Seymour et al. 2004). Participating in a coordinated multidisciplinary research program requires notably more time and effort than conducting research with undergraduates as a solo endeavor, but we found that students (and faculty) benefited greatly from this combined effort focused on a familiar local ecosystem.

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