FEATURE ARTICLE

Broadening Student Perceptions of Science through Participatory Data Collection & Research-Education Partnerships: A Case Study in California's Central Valley

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Abstract

We present results from the first year of a three-year extramurally funded project involving a partnership between an ethnically diverse urban high school and professional research botanists. The goals are to provide students exposure to real-world science, broaden interest in scientific fields of study, and increase floristic data and herbarium specimen collections in under-sampled areas of Solano County, California. A floristic survey was conducted in a 425-acre, open-space public park in Vacaville, California, that is actively grazed by cattle and characterized by grasses, forbs, and oaks. A total of 77 students were enrolled in the course associated with the partnership, and 47 participated in four visits to the collection site. Twenty-five unique plant specimens were collected, including 14 native and 11 introduced species. Results of a student perception survey suggest that the partnership has had a positive impact on students' understanding of scientific methodology and interest in pursuing a science career. Perception survey results were disaggregated by ethnicity; Hispanic students, more than any other group, indicated that they feel more confident in scientific research and writing skills. There was no significant difference between male and female students' responses.

Key Words: *diversity in science; collaborative education-research; botanical survey; California grassland; floristics.*

○ Background

The project described here began in 2018 with a formal collaboration between St. Patrick–St. Vincent Catholic High School, the Solano County Flora Project, and the Center for Plant Diversity in the Department of Plant Sciences at the University of California, Davis, intended to better understand the flora in open-space rangelands of California's Central Valley and to improve the quality of secondary-education science courses. The initial idea for the project came from the participating high school teacher; all partners worked together to design research methodology, create curricula, and write funding proposals.

> *"Long-term collaborations can empower teachers to employ dynamic project-based learning and foster an inclusive environment."*

The academic research partners include the Solano County Flora Project (Nomad Ecology) and the UC Davis Center for Plant Diversity, which includes the campus's herbarium, a collection of ∼300,000 pressed and dried plant specimens. Herbarium specimens are considered the "gold standard" for verifying the identification of plant species as well as their geographic and temporal distributions, and many of the specimens housed at UC Davis were gathered in the course of floristic and ecological studies in order to document the occurrences of particular species at particular places and times. The surveys conducted during this three-year project and the associated herbarium specimens will contribute to a more complete list of California species, especially in Solano County, and support local conservation efforts. In this way, the partnership described here mimics the citizen science model, using trained nonprofessionals to gather (potentially) large amounts of data over the long term (Poisson et al., 2020). Common risks often associated with citizen science programs, such as misidentifications, are minimized through the UC Davis and Nomad Ecology expert partners (Sumner et al., 2019).

St. Patrick–St. Vincent Catholic High School is a college-preparatory private high school with a student body of ∼500; it is located in Vallejo, California, which has been ranked among the top 100 most ethnically diverse U.S. cities (Allen & Turner, 1989). School-sponsored tuition scholarships have increased enrollment of low-income families and help the school serve a student body more reflective of the wider community (Figure 1).

Nationwide, women and ethnic minorities are consistently underrepresented in science and math department tenure-track positions (Nelson & Rogers, 2005). Math deficiencies in U.S. student applicant pools often lead to a higher percentage of international candidates selected for graduate science and engineering positions

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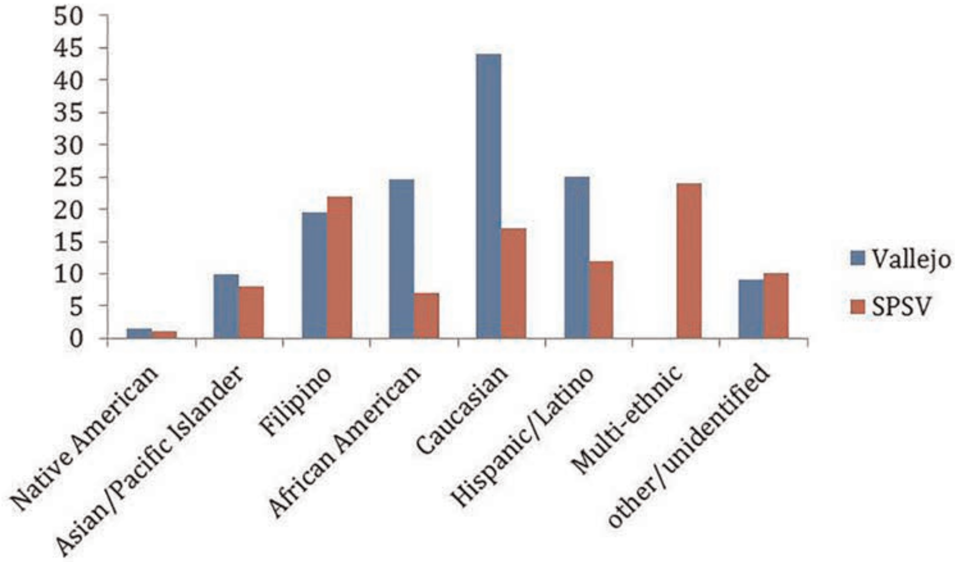

Figure 1. Demographic percentages for the city of Vallejo and St. Patrick–St. Vincent Catholic High School (SPSV). Sources: U.S. Census Bureau 2017 American Community Survey (Vallejo) and SPSV administrative documents (2017).

Figure 2. Research site with stratified sampling blocks.

(Subramanian & Clark, 2016). According to Burke and Mattis (2007), lack of opportunities to work with scientific equipment in high school, along with societal discrimination and gender bias, can lead to poor STEM (science, technology, engineering, and math) skill sets among women and minorities entering college. Also, women are more likely than men to pursue alternate careers, even after graduating with a STEM degree (Blickenstaff, 2005). Acknowledging these discrepancies and actively mentoring students to overcome these challenges by imparting a sense of inclusion, as well as encouraging original research contributions from high school science classes, have been shown to have positive impacts on increasing diversity in STEM college majors and career candidates (Burke & Mattis, 2007; Plaut, 2014). Blickenstaff (2005) recommends implementation of a curriculum that encourages cooperative group work and emphasizes ways in which science can improve life. In addition, multi-institutional collaborations may help increase student exposure to the level of research rigor they will be expected to handle in university science and math courses (O'Sullivan & Dallas, 2010). Furthermore, Subramanian and Clark (2016) found that strengthening partnerships between K–12 and higher-education institutions can support knowledge sharing in both directions. Educators share information about best teaching practices, and scientists impart research skills, with the ultimate goal of increasing students' understanding of scientific and mathematical concepts.

○ Methods

Prior to fieldwork, hands-on lesson plans were developed to prepare students for floristic research and plant identification. Activities were carried out both inside and outside of the classroom in a grassy and wooded area on campus with topography and vegetation similar to the research study site. After receiving instructions, students were given the opportunity to work in small groups and practice all steps of floristic research. Students were taught how to recognize and identify plants in the field by observing morphological characteristics (reproductive structures and leaf arrangement) based on treatments in *The Jepson Manual* (Baldwin et al., 2012). Lectures and activities on California's native flora, plant biology, and local herbarium history were also provided.

Field trips to the study area were carried out during select flowering times in April and September. During field excursions, participants took pictures and collected basic information about the landscape. The collected plant specimens were reviewed by taxonomists and staff at the UC Davis Center for Plant Diversity. To increase representation of vegetation communities associated with different soil types, and to ensure the safety and efficiency of student group sampling, a stratified random design was used (Roleček et al., 2007) following California Native Plant Society field protocols and guidelines (https://cnps.org). Specifically, the 425-acre research site was broken up into smaller sampling blocks, within which random plot locations were generated as described below. Plot size (5 m radius) and shape (circular) were determined on the basis of vegetation structure (mostly open grassland with scattered groups of trees and shrubs) as well as practical considerations of student supervision requirements (Kenkel et al., 1989). These plots were set up by students in the field (Figure 2). Working in groups, students used a random number generator, a 50 m tape, and a compass to randomly locate plots, linearly within the sampling blocks from lower to higher elevations. Plots were demarcated with flagging (instructions given to students are listed in

Figure 3. Students described specimens within randomly selected linear plots. Photos by P. Tomasini (left) and M. Paulson (right).

Figure 4. Specimens were pressed in a botanical plant press in the field. Photo by P. Tomasini.

Figure 5. *Hemizonia congesta* subsp. *luzulifolia* (DC.) Babc. & H.M. Hall – collected, pressed, and mounted by students during the study.

Appendix A). Within each plot, students described vegetation and land surface features as a qualitative narrative and collected plant samples using standard methods for voucher specimen collection and identification. The standard method for voucher specimen collection requires that the specimen be placed in a plant press (built with blotters and ventilators) in the field so that it can be dried and preserved as a museum-quality specimen. To estimate both frequency and diversity of species at the site, every different type of plant within the student plots was collected (with fertile tissue when available). After collection in the field, specimens were brought back to campus (Figure 4) and dried using a professional plant drier purchased through private grant funding. Plant specimens were examined by students and identified using a dissecting microscope and the Jepson eFlora dichotomous keys (https://ucjeps.berkeley.edu) (Figures 3 and 4). Students prepared voucher specimens for deposit in the Center for Plant Diversity Herbarium, University of California, Davis (Figure 5). Duplicate vouchers were retained in the classroom to build a teaching collection of local flora.

Perception surveys (Appendix B) were printed and provided to students after completion of all field-methods training and data collection to measure project impact. Survey participation was voluntary and students were given the option to remain anonymous (not write their name). To test the hypothesis that male and female students' perceptions of program impact were equal, we used a two-sample Student's t-test assuming equal variance (an F-test for variance was performed on the total survey data set, grouped by gender).

○ Results

A total of 25 different species were identified and deposited in the UC Davis Herbarium and referenced on its database (https://herbarium.ucdavis.edu) (e.g., Figure 5). The most frequently collected plant species and their origin status in California are shown in Table 1.

Survey statement responses had a varied distribution; the strongest agreement was with statement number 1, and the strongest disagreement was with statement number 5 (Table 2 and Figure 6). Response averages were disaggregated by ethnic identity (categories were obtained from parent responses on school admissions paperwork), with the strongest agreement per question highlighted in Table 3. Hispanic

Table 1. Most frequently collected species (2018–2019 botanical survey).

Family	Genus	Species	Status in California
Asteraceae	*Hemizonia*	*congesta* subsp. *luzulifolia* (DC.) Babc. & H.M. Hall	Native
Asteraceae	*Centaurea*	*solstitialis* L.	Naturalized invasive
Fabaceae	*Lupinus*	*bicolor* Lindl.	Native
Fagaceae	*Quercus*	*douglasii* Hook. & Arn.	Native
Geraniaceae	*Erodium*	*botrys* (Cav.) Bertol.	Naturalized

Table 2. Survey statement responses (n = 57[a]) (1 = strongly agree, 4 = somewhat agree, 7 = disagree).

Survey Statement	Average	1	2	3	4	5	6	7
1. This class, and our participation in the partnership project with UC Davis and Solano County Flora Project, has improved my understanding of real-world science projects.	3.21	10	13	12	6	10	5	1
2. My interest in pursuing a career in science has improved since the beginning of the year because of my involvement in this partnership.	3.98	8	5	9	13	9	6	7
3. I feel more confident in scientific research and writing skills since taking this course.	3.42	9	8	13	12	9	4	2
4. I feel more confident in environmental science field study methods since taking this course.	3.42	8	11	13	10	7	5	3
5. I will be more likely to select a science major because of my involvement in this UC Davis Solano County Flora Project partnership.	4.28	8	5	7	10	9	6	12

[a] Out of total enrolled students, 74% participated in the survey.

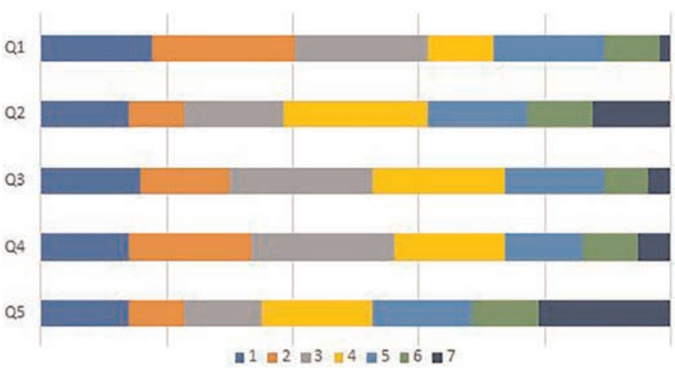

Figure 6. Statement response distribution.

students made up the largest portion of respondents (28%), followed by African American (24%), multiethnic (20%), Caucasian (17%), then Filipino (9%) and Pacific Islander (2%) participants. Gender of survey respondents was fairly evenly split (52% girls, 48% boys). The total mean survey responses of female and male students were not significantly different ($t_{278} = 1.44$, $P = 0.15$).

○ Discussion

In its first year, the project "Engaging High School Students in Botanical Surveys: A Collaborative Educational Research Program between UC Davis Plant Sciences Department, St. Patrick–St. Vincent Catholic High School and the Solano County Flora Project" has enhanced the scientific educations of an ethnically diverse group of high school students and has contributed to knowledge of the flora of Solano County and understanding of vegetation dynamics in urban open-space areas, with potential implications for management of these areas.

Open-space areas represent an important part of adjacent urban landscapes for maintaining biological diversity, wildlife habitat, public recreation, and educational opportunities. Partnerships that engage students in floristic data collection create opportunities for rapid assessment of areas to provide information on species composition, fill in flora gaps in under-surveyed areas, and provide valuable information to land managers. Although the limited scope of this study should be noted, preliminary floristic data provided by students suggest that actively grazed open spaces in the Central Valley have high native species diversity. However, invasive species were frequently encountered and may continue to outcompete and displace native herbs and grasses if left unmanaged.

The Likert survey results show that participating students, on average, perceived this collaborative education program to have had a positive impact on their scientific understanding, and the curriculum may have increased their likelihood of pursuing a science career. The strongest agreement expressed is with the statement "This class, and our participation in the partnership project with UC Davis and Solano County Flora Project, has improved my understanding of real-world science projects." Students also tended to agree that they feel more confident in their own scientific research, writing, and field-method skills after participating in the program. However, the relatively high number of students who

Table 3. Survey question response averages grouped by ethnic identity. [a]

Identity	Q1	Q2	Q3	Q4	Q5
Hispanic	3.133333333	3.333333333	2.733333333	3	3.2
African American	3.076923	5	3.615385	3.692308	5.230769
Multi-ethnic	2.909091	4.090909	3.727273	3.545455	4.636364
Caucasian	3.444444	4.111111	4.111111	3.777778	4.444444
Filipino	4.2	2.8	3.8	4	4.2
Pacific Islander	3	6	3	3	4

[a] Four survey respondents remained anonymous and/or did not select an ethnic identity category on admissions records and therefore were excluded from these calculations.

disagreed with the statement "I will be more likely to select a science major because of my involvement in this UC Davis and Solano County Flora Project partnership" suggests that antecedent interests greatly impact college major choice, regardless of any increase in scientific understanding or experience. Future perception surveys should include direct questions about past experiences with science (positive or negative) to improve understanding of how student baseline interest in the sciences may affect the impact of the program on their choice of college study.

There were no significant differences between male and female students' survey responses, signifying that the program impact was not gender biased. When survey responses were disaggregated by ethnic identity, Hispanic and Pacific Islander students showed the strongest agreement with statements 3, 4, and 5. Multiethnic and Filipino students had the strongest agreement with statements 1 and 2, respectively. Results suggest that engaging and authentic research-education partnerships, such as the one described here, may lead to increased representation of women and minorities in STEM majors and careers.

Long-term collaborations can empower teachers to employ dynamic project-based learning and foster an inclusive environment in which students are able to engage in original research. Preliminary data of multiyear projects provide the necessary resources to create curricula as the program moves forward. For example, advanced lessons on plant taxonomy can be developed as student collections build material for an in-house assemblage of voucher specimens. Also, initial student feedback acts as a formative assessment that drives modifications of the lesson plan and perception survey.

In conclusion, partnerships between K–12 professionals and university faculty create opportunities for students to direct their education journey beyond high school graduation, enrich secondary science education curricula, and expand data-collection capacities. We hope that the voucher specimens our students collected will be a lasting source of inspiration as they continue their educational journeys. Furthermore, it is our intention that high school teachers become encouraged to contact local university research faculty with partnership opportunities and ideas that engage students in genuine data collection.

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Appendix A: Student Instructions for Floristic Survey Plots

1. Once you reach your designated starting area, follow the steps below:
2. Using random.org, find two random numbers between 0 and 360: __________; __________ . These will be your random headings for two plots.
3. Now write two random numbers between 10 and 40 ________________; ____________
   These are your random number of paces you will walk.
4. Set your first random heading on your compass dial and turn your body to find your direction heading.
5. Walk your random number of paces.
6. When you reach the end of your steps, set up your plot with flags and meter tape (**5 m radius**).
7. Look at all the plants within your plot. **Take a picture of each plant in the plot**.
8. **EACH person in the group needs to collect and describe a unique plant**. Take a good sample (fruits and/or flowers/cones, leaves on stem, roots if possible) of each unique (different) plant within the plot.
9. **Fill out your data sheet for each sample** (use your compass app to get GPS coordinates and elevation).
10. Place the sample between newspaper and place your code (first and last initial followed by a new number) on the top of the newspaper AND on the data sheet.
11. Take a picture of the plant with the data sheet next to it, and the code visible.
12. Press the sample in the botanical press.
13. Use your second set of random numbers to locate and set up your second plot.
14. Repeat steps 7–12.

Appendix B: Student Perception Survey

This survey is designed to gauge the effectiveness of UC Davis–Solano County Flora Project–SPSV High School Partnership from a student perspective. We will be analyzing the results to determine if student participation in this partnership has had an effect on your interest in pursuing a career or college study in the sciences. Please answer honestly.

Name ____________________________ Grade level ______________

Directions: On a scale from 1 to 7, (1 = AGREE STRONGLY, 7 = DISAGREE), circle the number that most closely matches how you feel.

1. This class, and our participation in the partnership project with UC Davis and Solano County Flora Project, has improved my understanding of real-world science projects:						
1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Agree		Somewhat Agree		Disagree		

Continued

2. My interest in pursuing a career in science has improved since the beginning of the year because of my involvement in this partnership:						
1	2	3	4	5	6	7
Strongly Agree		Somewhat Agree		Disagree		
3. I feel more confident in scientific research and writing skills since taking this course:						
1	2	3	4	5	6	7
Strongly Agree		Somewhat Agree		Disagree		
4. I feel more confident in environmental science field study methods since taking this course:						
1	2	3	4	5	6	7
Strongly Agree		Somewhat Agree		Disagree		
5. I will be more likely to select a science major because of my involvement in this UC Davis–Solano County Flora Project partnership:						
1	2	3	4	5	6	7
Strongly Agree		Somewhat Agree		Disagree		