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ORIGINAL ARTICLE

e-Service-learning in an interdisciplinary course of plant and insect biodiversity and pollinator health

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Abstract

This article presents a synopsis of an interdisciplinary asynchronous online science service-learning course for upper undergraduates and graduate students. The design process, structure of the course, pedagogical approaches, and specific goals are described. Discussions, analyses, and evaluations from both students and university faculty highlight the experience and lessons learned from the process. Our study shows that our approach impacted students positively, including developing a more positive attitude toward biodiversity protection and some behavioral changes in their personal life as well as their professional life.

1 | INTRODUCTION

Despite increasing public awareness of the importance of sustainability, biodiversity continues to decline and conservation problems abound (Chapman et al., 2015; Rands et al., 2010). In the trophic pyramid, as producers on which the rest of the biosphere relies, plants are critical. Insects occupy the second largest level above plants, which denotes their importance to the rest of the trophic levels. It is estimated that 87.5% of flowering angiosperms rely on animal pollination for seed set (Ollerton et al., 2011). From human perspective, insect pollination not only has an enormous global food production value, but also plays a critical life-support mechanism underpinning biodiversity and ecosystem health (Delaplane, 2021; Vanbergen, 2013). Global pollinator declines have been reported (Vasiliev & Greenwood, 2021; Zattara & Aizen, 2021) due to habitat fragmentation and loss, pesticide usage, disease, parasites, competition with invasive species, and climate change (Dicks et al., 2021; Ulyshen & Horn, 2023; Wagner et al., 2021). Non-profit organizations such as the Xerces Society have worked to increase awareness and provide resources to landowners, crop producers, and the public to combat the loss of invertebrates and their habitats (Xerces Society, 2023). Citizen science endeavors for pollinator conservation have been launched (e.g., www.bumblebeeatlas.org; www.GSePC.org) and led many private and public organizations to encourage the use of native plants in human landscapes to mitigate habitat loss (State Botanical Garden of Georgia, 2023; United States Department of Agriculture, 2021). As the public turns to academia to seek knowledge and to share their willingness to help, we as teachers must ensure that the next generation of college-educated practitioners have the background, training, and skills to do their part. The requisite knowledge is interdisciplinary in nature

Abbreviations: e-SL, e-service-learning; SL, service learning.

(e.g., botany/horticulture and entomology), and at least in part, it should be gained by real-world observation and practical exercise.

Service learning (SL) has been defined as a pedagogical approach based on experiential learning (Salam et al., 2019; Sparkman-Key et al., 2020). By its nature, SL engages students in carefully organized activities that link specific course objectives to identified community needs (Bringle & Hatcher, 1999). Furthermore, students are expected to reflect on the service activity in such a way as to gain deeper understanding of course content, a broader appreciation of the discipline, and enhanced perception of personal values and civic responsibility (Bringle & Hatcher, 1999). In the 21st century where many academic institutions have increased their online course offerings, and especially post Covid-19 pandemic (Culcasi et al., 2022), the traditional SL has moved into the digital environment to take the form of e-service-learning (e-SL; Waldner et al., 2010). e-SL has been successfully used in different formats, from e-SL Hybrid Type 1 to extreme e-SL, reflecting the increasing levels of virtual delivery of both service and instruction components (Waldner et al., 2010). e-SL has even been explored for its potential to teach soft skills (Culcasi et al., 2022).

The objective of this article is to share our methodology and pedagogical approach in designing and teaching an interdisciplinary, asynchronous, online science SL course to promote biodiversity and pollinator health with real-world applications. We also share student perspective in how they perceived their experience and potential for future civic and environmental engagement.

Core Ideas

- College education can respond to the pressing need for training on pollinator health in an online environment.
- A course can be designed to achieve multiple goals—interdisciplinary knowledge, practical skills, and experiential learning.
- Engagement with subject matter has been achieved in real-world scenarios by carefully designed activities.
- According to multiple metrics, the course has been well received.

2 | COURSE OVERVIEW

The course titled "Plants, Pollinators, and You" aims to teach students the impact of urban systems on pollinator health and the active role citizens can play in protecting pollinators. Specifically, the course is designed to teach plant and pollinator identification to better understand plant–pollinator interactions, the factors contributing to pollinator declines, and creating a coexisting pollinator and plant habitat in the urban matrix. The course is cross-listed with two academic departments, horticulture and entomology, dual-level (undergraduate and graduate), and offered 100% in asynchronous online format. It is taught in the summer over an 8-week period (through term semester, June and July).

The course has general science prerequisites, such as biology and/or chemistry. Both graduate and undergraduate students come from various majors, with majority from horticulture, entomology, plant protection and pest management, landscape architecture, agricultural leadership and communications, and general biology (premed and pre-vet majors). The course has been offered in summer 2019, 2020, 2021, 2022, and 2023 with enrollments of 31, 64, 100, 75, and 71 students, respectively.

2.1 | Structure of the course and pedagogical approach

The content is structured in seven modules (Table 1). First part of the course centers around plants and the second part centers on insects. The first three modules focus on general biodiversity concepts, plant species selection with emphasis on resource-rich species and types common in urban landscapes; modules 4–6 focus on insects, pollinators and other beneficial arthropods; the last module is mainly centered on completing an SL project (also referred to as a capstone project). Modules 1, 2, 4, and 5 are focused on building the related knowledge foundation, while modules three and six connect the knowledge with real-world applications.

The plants parts I and II include general information on taxonomy, with emphasis on the families Asteraceae and Lamiaceae because of their high arthropod value and also preponderance in managed and urban landscapes (including weeds). Other resource-rich families and genera are also covered, for example milkweeds, grasses, and trees as larval hosts for lepidopterans. Native versus exotic plant status was introduced, and information on cultivated vegetation versus unmanaged weeds (some of which are native wildflower species with high value for insects) was shared. We took a balanced approach, where flora in urban landscapes was presented in the framework of human needs (aesthetics) as well as arthropod value. Module 3 discusses essential elements of a pollinator habitat.

Module 4 introduces basics of insect taxonomy (emphasis on Insecta), insect growth development (complete and incomplete metamorphosis), functional groups (pollinator, decomposer, predator, parasitoid, and herbivore), and ecosystem

TABLE 1 Class structure, learning activities, and points available for each activity.

Module topic	Learning content	Learning activities	Points
M1: Intro and plants part I	Five short lectures	Assignment: Plant profile	30
		Two quizzes	40
M2: Plants part II	Four short lectures	Assignment: Plant profile	30
		Two quizzes	40
M3: Issues and opportunities in plant selection	One lecture and 12 articles	Discussion: Recording a public service announcement video on plant selection	60
M4: Overview of insects	Four short lectures	Assignment: Insect profile	30
		Two quizzes	40
M5: Pollinators	Four short lectures	Assignment: Insect profile	30
		Two quizzes	40
M6: Selected topics in entomology	One lecture and 11 articles	Discussion: Recording a public service announcement video on pollinator conservation	60
M7: Capstone project		Perform a landscape evaluation and write a report	120

services (pollination, nutrient cycling, biological control, and food provision). Examples of major herbivorous pests are also included. Module 5 centers on pollinating insects, including major families of flies, beetles, butterflies, and moths, wasps, and bees. As the most important pollinating group, bees receive the most attention in tour course—life cycle (including parasitic), sociality, and nesting habit. The five bee families occurring in North America and common genera in the Southeastern US are included. Module 6 presents the statewide Georgia Pollinator Protection Plan as an example of policy and recommendations for stakeholders.

To build a solid knowledge foundation, modules 1, 2, 4, and 5 include four to five short lectures, quizzes, and written assignments. Short lectures illustrate the key concepts and quizzes are used to help students comprehend these foundational concepts and knowledge. For the written assignments, students are asked to develop plant and insect profiles. For example, in module 1, students are asked to develop plant profiles for five species: two species of Asteraceae, two species of Lamiaceae (the top two botanical families with regards to floral provisioning), and one “wild card” plant (any plant that grows wild). In module 4, students are asked to develop insect profiles for five species and to include one of each functional group (pollinator, decomposer, predator, parasitoid, and herbivore). For all written assignments, students are expected to furnish firsthand observation of plants and insects, complete with visual and/or video submission.

For ease and convenience, students are directed to visit plant trial gardens on campus or in an area where they are located, as well as botanical gardens and garden centers where plants are helpfully labeled, and available in a wide selection. A digital workbook (Figure 1) is also provided to help students as they develop their plant and insect profiles. The workbook contains fillable pages, and links specific lecture notes to the practical assignment and observations.

2.2 | Connecting knowledge to the public life through real-world projects

To help students connect the knowledge they learned from this class to the real-world context, two types of course projects were designed and incorporated into this course: real-world scenarios and the landscape evaluation project.

2.2.1 | Real-world scenarios

We use two real-world scenarios to help students connect what they learned in class to public life and the community. These activities are accomplished through online discussion format, which allows students to share information, comment on each other’s posts, and learn from each other. In module 3, after exploring current journal papers on issues and opportunities in plant selection, students are asked to serve as a spokesperson for a landscaping company named “Bee Heaven,” which specializes in pollinator protection. Students are divided into two teams: one team is responsible for plant selection and the other is responsible for landscape maintenance.

In the plant selection group, students are required to use scientific information from the assigned readings to support their plant recommendations (native vs. non-native plant species) and incorporate a defined plant list provided by homeowner association (HOA); in the landscape maintenance group, students are required to explore alternative approaches to traditional landscape maintenance (e.g., reducing mowing

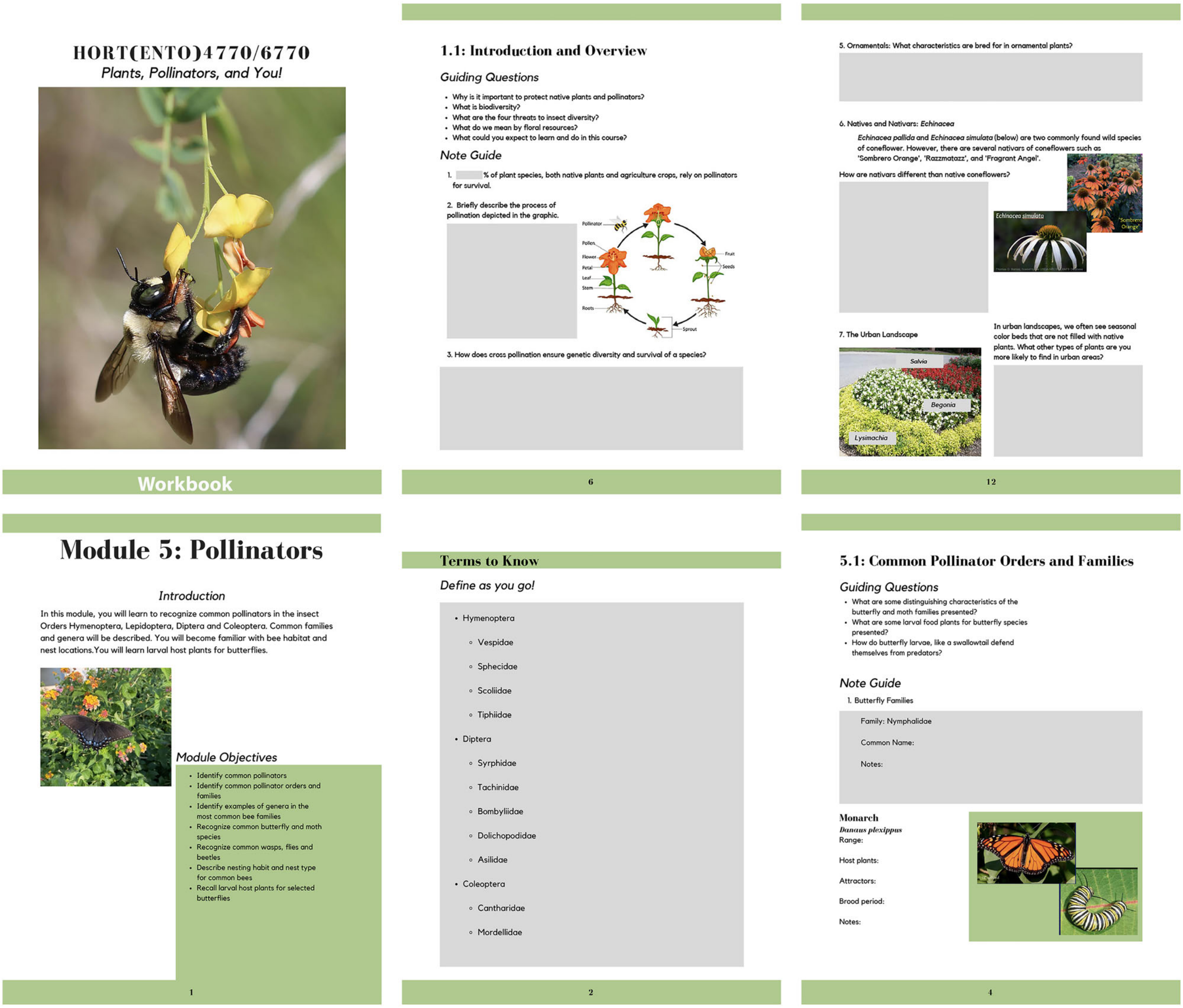

FIGURE 1 Examples of pages in the digital workbook; grey areas indicate fillable fields.

frequency to allow flowering weeds in the lawn, leaving bare patches of soil for ground-nesting bees, etc.) and convince the HOA board to go with their approaches (based on environmentally sound practices for pollinator protection). This scenario sets up the student as a pollinator health advocate, and the HOA as the customer.

In module 6, students are asked to communicate the value of incorporating pollinator conservation and protection into urban planning and municipal management to urban planners and city managers. Here too, students are divided into two groups: one group is tasked with communicating convincingly with the general public about the importance of conserving insect diversity (including topics on ecological function, economic value, and risk of decline); the other group presents the opportunities and impediments to design and implementation of pollinator conservation in the urban environment. In both activities, each student is required to record a short video (3 min) presentation and post it on a discussion board.

2.2.2 | The SL landscape evaluation project

In SL (capstone project), students are required to apply knowledge learned in the course to assess a real landscape for its potential to support pollinators. It is essential for students to work with a community partner so that their work would benefit the partner. Students should choose a landscape associated with any public building (or a commercial building, provided there was mutual interest). They are directed to obtain written permission from the community partner to take photographs and do the evaluation. A formal letter signed by the instructors and describing the goals of the activity is made available to students. Two landscape evaluation/assessment tools are offered to the students, one developed in-house by the instructor, and the other developed by the Xerces Society for Invertebrate Conservation (Xerces Society, 2023; Figure 2). Both tools contain detailed rubrics including vegetation selection, type, bloom phenology, floral provisioning,

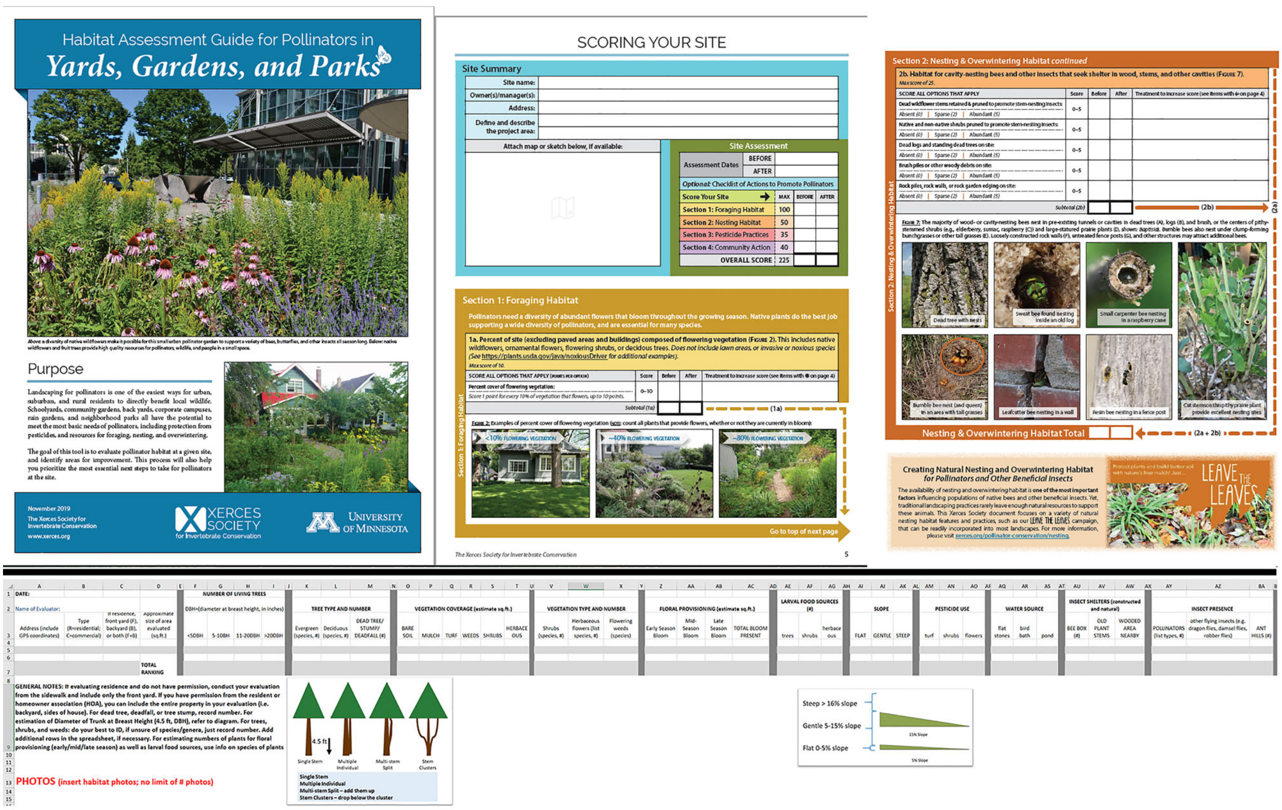

FIGURE 2 Landscape evaluation/assessment tools used in the service-learning project. Top row pages from Habitat Assessment Guide by Xerces (www.Xerces.org). Bottom image from spreadsheet developed in-house. Students have a choice to use either tool in their projects.

bee nesting habitat, cultural practices such as weed management (in particular the use of pesticides for pest and weed management), among others. At the end, students are also required to send the completed report to the community partner and record a short reflection video (1 min) about their experience.

Felten and Clayton (2011) pointed out that SL is most effective at generating significant educational outcomes when "the experience is integrative, bridging what students do in and out of class and connecting perspectives and knowledge from the full range of participants" (p. 81). Speck (2001) also suggested that SL could help prepare students to participate in public life and integrate theory into practice.

2.3 | Graduate level work

Graduate students and undergraduate students registered for graduate credit are asked to write a research and/or outreach proposal based on a pollinator conservation topic (e.g., habitat management, landscape enhancement by floral resources, etc.). The topic is chosen in consultation with the instructors. The students are responsible for writing a proposal that is complete with relevance, objectives, layout, plant recommendations, budget, and the timeline for completion. A research proposal form provides a template for students to use.

Our specific learning objectives for the graduate level work are as follows: (1) students should be able to write a cohesive, substantive, and pertinent grant proposal based on the course material; (2) develop a research/outreach proposal based on an original idea and consisting of all major parts of a typical grant proposal: literature review, objectives, plan of work, budget, timeline, and deliverables; (3) apply the scientific method; formulate a hypothesis(es) congruent with the research question(s) posed and design experiments to test the hypothesis(es); (4) formulate clear and achievable objectives to be completed in the specified timeframe and within the budget; (5) frame clear and reachable deliverables; and (6) demonstrate graduate-level writing skills with persuasive arguments and cogent scientific terminology.

2.4 | Impact on students' attitude and behaviors toward biodiversity protection

In summer 2022, pre-course and post-course surveys were developed to assess whether the course changed students' attitude and behaviors toward biodiversity protection. The survey instrument was evaluated by the University of Georgia Office of Human Subjects (STUDY 00005887) and assigned a determination of Not Human Research. A total of 30 students

TABLE 2 Students' attitude toward biodiversity protection in the post-course survey.

Post-course survey items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean[a]
I can make a difference in protecting biodiversity in the community.	1	0	0	7	22	4.633
I feel an obligation to protect biodiversity.	1	0	0	7	21	4.467
I feel confident in my ability to apply related knowledge and skills learned to protect native plants and beneficial insects in the community.	1	0	0	10	19	4.533
I feel confident in my ability to communicate effectively with the public and be an advocate for protection of biodiversity.	1	0	0	13	16	4.433
I feel confident in my ability to communicate effectively with the scientific community, including fellow students and be an advocate for protection of biodiversity.	0	1	0	16	13	4.367
I feel confident to apply related skills and knowledge to assess a real landscape for its potential to support pollinators and beneficial insects.	1	0	1	9	19	4.500
I plan to participate in project(s) to protect biodiversity in the community in the next year.	0	0	7	14	9	4.067
I would seek out an opportunity to protect biodiversity in the community in the next year.	0	0	4	12	14	4.333
I would seek to increase my scientific knowledge of native plants in the near future.	0	0	2	11	17	4.500
I would seek to increase my scientific knowledge of pollinators and other beneficial insects in the near future.	0	0	1	12	17	4.533

Note: $n = 30$; the mean is calculated based on assigning 1–5 to strongly disagree to strongly agree.

agreed to participate in this study and completed both the pre-course and post-course surveys. The participants came from various disciplines: 14 from biology-related major, seven from horticulture-related major, three from entomology, and the remaining six from psychology, science education, geography, and environmental resource science majors. Among these 30 participants, there were 24 undergraduate students and six were graduate students.

2.4.1 | The change in students' attitude

Table 2 shows students' overall attitude toward biodiversity protection at the end of the course. Based on the results, most students agree or strongly agree that they are confident in their ability to assess a real landscape for its potential to support pollinators and beneficial insects, apply related knowledge and skills to protect native plants and beneficial insects in the community, and communicate effectively with the public as well as the scientific community for advocating biodiversity protection. Most of them also believe that they can make a difference in protecting biodiversity in the community and feel an obligation to do so.

Most of the participants agree or strongly agree that they would seek to increase their scientific knowledge of native plants and pollinators as well as other beneficial insects in the near future. Although around 20.6% of participants are neutral to whether they plan to participate in community biodiversity protection projects in the next year, the rest of them agree or strongly agree that they plan to do so. Most of them also agree or strongly agree that they would seek opportunities to protect biodiversity in the community next year.

We also compared students' attitude toward biodiversity protection in pre-course survey with that of post-course survey. The data were neither normally distributed, nor was the distribution of the differences between the two samples symmetrical, therefore paired-samples sign test was conducted. The results of the comparison (Table 3) show that students' attitude toward biodiversity protection in the post-course survey is significantly more positive than that of the pre-course survey. They generally feel more confident in their ability and are more willing to participate in biodiversity protection activities. They are also more willing to increase their knowledge of native plants and beneficial pollinators in the near future.

2.4.2 | The change in students' behavior

Students were asked how many biodiversity protection projects they participated in the community this summer (excluding the class project). Eight out of 30 students participated in one or two biodiversity protection projects. The

TABLE 3 Comparison of students' attitude toward biodiversity protection in the pre- and post-course surveys.

Survey items		Mean	SD	Significance, *p* value
I can make a difference in protecting biodiversity in the community.	Pre	4.20	.551	$p < .001$
	Post	4.63	.809	
I feel an obligation to protect biodiversity.	Pre	3.93	.704	$p < .000$
	Post	4.62	.820	
I feel confident in my ability to apply related knowledge and skills learned to protect native plants and beneficial insects in the community.	Pre	3.07	1.015	$p < .000$
	Post	4.53	.819	
I feel confident in my ability to communicate effectively with the public and be an advocate for protection of biodiversity.	Pre	2.97	1.098	$p < .000$
	Post	4.43	.817	
I feel confident in my ability to communicate effectively with the scientific community, including fellow students and be an advocate for protection of biodiversity.	Pre	3.07	.961	$p < .000$
	Post	4.37	.669	
I feel confident to apply related skills and knowledge to assess a real landscape for its potential to support pollinators and beneficial insects.	Pre	2.90	1.062	$p < .000$
	Post	4.50	.861	
I plan to participate in project(s) to protect biodiversity in the community in the next year.	Pre	3.33	.758	$p < .000$
	Post	4.07	.740	
I would seek out an opportunity to protect biodiversity in the community in the next year.	Pre	3.53	.860	$p < .000$
	Post	4.33	.711	
I would seek to increase my scientific knowledge of native plants in the near future.	Pre	4.14	.693	$p < .05$
	Post	4.50	.630	
I would seek to increase my scientific knowledge of pollinators and other beneficial insects in the near future.	Pre	4.17	.531	$p < .05$
	Post	4.53	.571	

Note: $n = 30$ or 29 due to a few missing data; the mean is calculated based on assigning 1–5 to strongly disagree to strongly agree.

biodiversity protection activities they had done included adding native plants to their garden, letting the lawn be more bee-friendly, adding different native and non-native pollinator plants in their landscape design work, working as volunteers to serve the community through monarch conservation projects, offering pollinators classes, and building planting beds for schools.

Rosenberg (2000) pointed out that SL should empower students by making them responsible in a real-world context through giving them the necessary support, encouragement, information, and skills. Therefore, besides attitude change, it is important to check whether the SL course impacted students' behaviors.

In our survey, 23% of students were neutral as to whether they would participate in biodiversity projects in the next year. It is possible that if we had asked for their intentions for the next 5 years, we could have received a more positive response. Ultimately, to gauge whether students become actively involved in pollinator protection, we should conduct post-graduation surveys.

3 | JUSTIFICATION AND CHALLENGES IN CREATING THE e-SL COURSE

Threats to biodiversity and pollinator health have been highlighted in the public arena and in research circles for over a decade (Barnosky et al., 2011; Vanbergen, 2013). Although numerous national and state citizen initiatives exist, academia has been slow in formal training on the subject and to provide students with the skills and attitudes necessary to become active in solving social problems (Speck, 2001). Numerous barriers exist in developing an interdisciplinary SL course due to its interdisciplinary, experiential, reflective, nonhierarchical, and unpredictable nature (Felten & Clayton, 2011). The subject matter entails broad and advanced background to teach the interdisciplinary knowledge; it requires that the instructor is familiar with the corresponding practical application and skills necessary, and it involves reciprocal collaboration among students, faculty, and community members/organizations. In addition, for most online courses, it is not only challenging to create hands-on opportunities, but also to do so in a compressed time frame of summer semester (8 weeks instead of the typical 15 weeks). Both plants and insects are best observed during the warmest part of the year (highest insect activity and most blooming species); abundant bloom attracts the insect visitors and in turn allows the students to make firsthand observations of the interaction.

Despite the numerous challenges, opportunities existed; we believe that the most responsible and efficient way to promulgate the knowledge and practices in the world and achieve impact is by assuring an in-depth and dynamic training of college-level professionals. We felt strongly that the time was right for developing and teaching this course. The virtual format during summer allowed students who had other obligations to take the course and fulfill two of the University-level requirements—an upper science elective and an experiential learning course. The SL format is essential in achieving a course objective, namely, to begin transforming the student into an advocate for biodiversity and pollinator health, and a citizen, actively engaged in environmental stewardship.

4 | CONSIDERATIONS FOR FUTURE ONLINE SL COURSES

The interdisciplinary approach has been critical in providing students with entomological-based knowledge (i.e., Integrated Pollinator and Pest Management) and pollinator health while also incorporating horticultural concepts such as ornamental plant species for maximum aesthetic impact and floral provisioning, and best management practices in the urban landscape. The course empowers students to engage in citizen science and work closely with outside partners to provide practical and impactful information to protect pollinators in urban settings. The three parts—entomological knowledge, horticultural knowledge, and the human elements—are crucial in mitigating the negative aspects of urbanization, that is, loss of natural habitats and biodiversity declines.

Although we have garnered informal comments from community partners over the 3 years, we have not initiated a formal and detailed assessment. So far, the input provided has been overwhelmingly positive, with partners sharing how much they have learned and enjoyed the interaction with our students. Going forward, we plan to conduct formal surveys to assess whether and to what extent the SL experience actually impact our community partners. We likely will revise our surveys of students to find out whether and to what extent the SL experience impacted their future career choice, and to what extent the SL experience impacted students' behavior from both personal and professional perspectives.

In the grand scheme of protecting plant and animal biodiversity, we as teachers and scientists have a duty not only to impart to students pertinent, current scientific knowledge, but also equip them with the best practices in applying this knowledge outside the classroom, so that promulgation of said practices ensures rapid and meaningful change in the real world. We consider this SL course successful and hope our experience could provide some insights to other educators who are interested in offering interdisciplinary e-SL courses.

AUTHOR CONTRIBUTIONS

Dan Ye: Conceptualization; formal analysis; methodology; validation; visualization; writing—original draft. **Svoboda V. Pennisi**: Conceptualization; investigation; project administration; resources; visualization; writing—original draft; writing—review and editing. **Susan Kristine Braman**: Writing—review and editing. **Christy M. Rich**: Writing—review and editing.

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The survey instrument was evaluated by the University of Georgia Office of Human Subjects (STUDY 00005887) and assigned a determination of Not Human Research. The survey tool conforms to recognized standards.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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REFERENCES

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O., Swartz, B., Quental, T. B., Marshall, C., McGuire, J. L., Lindsey, E. L., Maguire, K. C., Mersey, B., & Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, *471*, 51–57. https://doi.org/10.1038/nature09678

Bringle, R. G., & Hatcher, J. A. (1999). Reflection in service learning: Making meaning or experience. *Evaluation/Reflection*, *23*, 179–185.

Chapman, J. M., Algera, D., Dick, M., Hawkins, E. E., Lawrence, M. J., Lennox, R. J., Rous, A. M., Souliere, C. M., Stemberger, H. L. J., Struthers, D. P., Vu, M., Ward, T. D., Zolderdo, A. J., & Cooke, S. J. (2015). Being relevant: Practical guidance for early career researchers interested in solving conservation problems. *Global Ecology and Conservation*, *4*, 334–348. https://doi.org/10.1016/j.gecco.2015.07.013

Culcasi, I., Russo, C., & Cinque, M. (2022). E-Service-Learning in higher education: Modelization of technological interactions and measurement of soft skills development. *Journal of Higher Education Outreach and Engagement*, *26*, 39–51.

Delaplane, K. S. (2021). *Crop pollination by bees, Volume 1: Evolution, ecology, conservation, and management* (2nd ed.). CAB International.

Dicks, L., Breeze, T. D., Ngo, H. T., Senapathi, D., An, J., Aizen, M. A., Basu, P., Buchori, D., Galetto, L., Garibaldi, L. A., Gemmill-Herren, B., Howlett, B. G., Imperatriz-Fonseca, V. L., Johnson, S. D., Kovács-Hostyánszki, A., Kwon, Y. J., Lattorff, H. M. G., Lungharwo, T., Seymour, C. L., … Potts, S. G. (2021). A global-scale expert assessment of drivers and risks associated with pollinator decline. *Nature Ecology & Evolution*, *5*(10), 1453–1461. https://doi.org/10.1038/s41559-021-01534-9

Felten, P., & Clayton, P. H. (2011). Service-learning. *New Directions for Teaching and Learning*, *2011*(128), 75–84. https://doi.org/10.1002/tl.470

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos*, *120*, 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x

Rands, M. R. W., Adams, W. M., Bennun, L., Butchart, S. H., Clements, A., Coomes, D., Entwistle, A., Hodge, I., Kapos, V., Scharlemann,

J. P., Sutherland, W. J., & Vira, B. (2010). Biodiversity conservation: Challenges beyond 2010. *Science*, *329*(5997), 1298–1303. https://doi.org/10.1126/science.1189138

Rosenberg, L. (2000). Becoming the change we wish to see in the world: Combating through service learning learned passivity. *Academic Exchange Quarterly*, *4*, 6–11.

Salam, M., Iskandar, D. N. A., Ibrahim, D. H. A., & Farooq, M. S. (2019). Technology integration in service-learning pedagogy: A holistic framework. *Telematics and Informatics*, *38*, 257–273. https://doi.org/10.1016/j.tele.2019.02.002

Sparkman-Key, N., Anthony, V., & Belcher, T. (2020). Advancing human services education: Exploratory study of international service-learning and digital pedagogy. *Journal of Service-Learning in Higher Education*, *10*, 29–45.

Speck, B. W. (2001). Why service-learning? *New Directions for Higher Education*, *114*, 3–13. https://doi.org/10.1002/he.8

State Botanical Garden of Georgia, University of Georgia. (2023). *Conservation and science: Connect to protect*. https://botgarden.uga.edu/conservation-science/connect-to-protect/

Ulyshen, M., & Horn, S. (2023). Declines of bees and butterflies over 15 years in a forested landscape. *Current Biology*, *33*(7), 1346–1350. https://doi.org/10.1016/j.cub.2023.02.030

United States Department of Agriculture: Natural Resources Conservation Service. (2021). *NRCS documents and resources for pollinator conservation and enhancements*. https://plants.usda.gov/assets/docs/NRCS_Pollinator_PLANTS_Nov2021.pdf

Vanbergen, A. J. (2013). Threats to an ecosystem service: Pressure on pollinators. *Frontiers in Ecology and the Environment*, *11*(5), 251–259. https://doi.org/10.1890/120126

Vasiliev, D., & Greenwood, S. (2021). The role of climate change in pollinator decline across the Northern Hemisphere is underestimated. *Science of The Total Environment*, *775*, 145788. https://doi.org/10.1016/j.scitotenv.2021.145788

Wagner, D. L., Grame, E. M., Forister, M. L., Berenbaum, M. R., & Stopak, D. (2021). Insect decline in the Anthropocene: Death by a thousand cuts. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(2), e2023989118. https://doi.org/10.1073/pnas.2023989118

Waldner, L., McGory, S., & Widener, M. (2010). Extreme E-service learning: E-service learning in the 100% online course. *MERLOT Journal of Online Learning and Teaching*, *6*(4), 839–851.

Xerces Society for Invertebrate Conservation. (2023). *Region-specific resources to aid in the planning, establishment, restoration, and maintenance of pollinator habitat*. www.xerces.org/pollinator-resource-center

Zattara, E. E., & Aizen, M. A. (2021). Worldwide occurrence records suggest a global decline in bee species richness. *One Earth*, *4*, 114–123. https://doi.org/10.1016/j.oneear.2020.12.005

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