

1 **Potential for urban agriculture to support accessible and impactful undergraduate biology
2 education**

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29

30

31 **Abstract**

32

33 Active-learning in STEM education is essential for engaging the diverse pool of scholars needed to
34 address pressing environmental and social challenges. However, active-learning formats are difficult to
35 scale and their incorporation into STEM teaching at U.S. universities varies widely. Here, we argue that
36 urban agriculture as a theme can significantly increase active learning in undergraduate biology
37 education by facilitating outdoor fieldwork and community-engaged education. We begin by reviewing
38 benefits of field courses and community engagement activities for undergraduate biology and discuss
39 constraints to their broader implementation. We then describe how urban agriculture can connect
40 biology concepts to pressing global changes, provide field research opportunities, and connect students
41 to communities. Next, we assess the extent to which urban agriculture and related themes have already
42 been incorporated into Biology-related programs in the U.S. using a review of major programs, reports
43 on how campus gardens are used, and case studies from five higher education institutions (HEIs)
44 engaging with this issue. We found that while field experiences are fairly common in major Biology
45 programs, community engagement opportunities are rare, and urban agriculture is almost nonexistent
46 in course descriptions. We also found that many U.S. HEIs have campus gardens but evidence suggests
47 that they are rarely used in Biology courses. Finally, case studies of five HEIs highlight innovative
48 programming but also significant opportunities for further implementation. Together, our results
49 suggest that urban agriculture is rarely incorporated into undergraduate biology in the U.S., but there
50 are significant prospects for doing so. We end with recommendations for integrating urban agriculture
51 into undergraduate biology, including the development of campus gardens, research programs,
52 community engagement partnerships, and collaborative networks. If done with care, this integration
53 could help students make community contributions within required coursework, and help instructors
54 feel a greater sense of accomplishment in an era of uncertainty.

55

56 **Key words:** Active learning, community engagement, field course, sustainability.

57 **INTRODUCTION**

58 Undergraduate attrition from science fields is a significant problem in the United States. Less than 40%
59 of U.S. students (and ~20% of students from underrepresented groups) who start university with an
60 interest in STEM actually graduate with a STEM degree (PCAST 2012). This attrition contributes to a
61 shortage of available science and health professionals and teachers (Chen 2013, Chen et al. 2018) and
62 represents lost investments for the students who switch majors or drop out altogether. Attrition of
63 underrepresented students is particularly worrisome given that a diverse community of scientists
64 reduces bias in scientific reasoning and makes science more inviting to a broader talent pool (Intemann
65 2009, Sulik et al. 2021). Moreover, selective attrition negatively impacts classroom dynamics by reducing
66 the range of identities and backgrounds contributing to the educational process.

67

68 One reason identified for STEM attrition is because science content and class activities can seem
69 inaccessible and lack relevance, especially for first generation college students from a variety of
70 economic, racial, and ethnic backgrounds (Estrada et al. 2016, Seymour and Hunter 2019). Concepts in
71 biology involve complex processes at scales that can be difficult to perceive. Furthermore, introductory
72 laboratories are often built around easy-to-follow procedures where instructors know what the results
73 will be, leaving students with the impression that biology—and more generally, the scientific method—
74 involves following established protocols and measuring expected outcomes. In addition, STEM
75 instruction rarely connects to pressing social challenges that many students are keenly aware of.

76

77 Recent summaries of education research have suggested ways to address these shortcomings. The 2011
78 American Association for the Advancement of Science (AAAS) *Vision and Change* report outlined
79 guidelines to improve undergraduate biology education and highlighted core concepts and
80 competencies required for modern biologists (AAAS 2011, Figure 1). It emphasized integrating these
81 core concepts and competencies throughout the curriculum and focusing on students as active
82 participants in the educational process, among other recommendations. To help students develop this
83 conceptual understanding and these competencies, programs began moving from lecture to active-
84 learning formats (Freeman et al. 2014) and created course- and non-course-based undergraduate
85 research experiences (Bangera and Brownell 2014). Evidence suggests that this movement has had
86 particular benefits for STEM students from underrepresented backgrounds and for female students in
87 male-dominated fields (Haak et al. 2011, Odom et al. 2021). Subsequent reports have emphasized the
88 overwhelming evidence from educational research about the benefits of active-learning innovations
89 that have increased student engagement by creating student-centered, inquiry-rich experiences
90 (Laursen 2019).

91

92 However, despite their educational benefits, immersive, active-learning formats are often difficult to
93 scale and the extent to which they have been incorporated into STEM teaching at U.S. universities varies
94 widely (Stains et al. 2018, Laursen 2019, Nguyen et al. 2021). Two approaches for scaling up active
95 learning in biology involve the incorporation of outdoor fieldwork (Easton and Gilburn 2012) and the use
96 of community-engaged education (Hansen et al. 2021). Although both approaches have been shown to
97 improve learning outcomes in undergraduate students, both face significant barriers to broad
98 implementation in biology (described more thoroughly below).

99

100 Here we argue that urban agriculture, which includes everything from backyard urban gardening to
101 large-scale food production operations in cities (Wortman and Lovell 2013), has a largely untapped
102 potential to integrate field experiences and community-engaged education into undergraduate biology
103 education. Urban agriculture can provide active learning, research-intensive educational experience in a
104 way that can be practically applied to a large number of students. At the same time, development of

105 undergraduate biology experiences around urban agriculture can help biology departments and their
106 universities develop lasting and mutually beneficial engagements with community organizations that
107 can in turn inspire student learning.

108
109 We begin with an overview of potential educational benefits of field work and community engagement
110 for undergraduate biology and discuss constraints to implementation. We then describe how urban
111 agriculture programs can help to overcome these constraints. We assess the extent to which urban
112 agriculture has been incorporated into undergraduate biology curricula using both a review of major
113 programs and an analysis of a database from the American Association for Sustainability in Higher
114 Education (AASHE), and present case studies of urban agriculture activities in bioscience departments at
115 five higher education institutions. Finally, we make recommendations for how to incorporate urban
116 agriculture into undergraduate biology education. Given our collective expertise, we focus our
117 discussion on higher education institutions (HEIs) in the United States, but we hope that it can help with
118 reform in undergraduate biology education in other countries as well. While our presentation in some
119 ways parallels calls for the development of “sustainable food systems education” aimed at future
120 professionals (e.g., Sterling et al. 2021), we suggest instead that incorporating urban agriculture into
121 undergraduate biology will benefit all biology students, regardless of careers interests, by engaging
122 them in basic science and exposing them to pressing community challenges.

123
124 **BENEFITS AND CHALLENGES TO FIELD-BASED AND COMMUNITY-ORIENTED BIOLOGY EDUCATION**

125 Although field (outdoor) experiences have long been viewed as essential to biology education, recent
126 reviews have documented the decline in field-oriented courses in U.S. higher education (Easton and
127 Gilburn 2012, Fleischner et al. 2017). Field courses can engage students in active, research-oriented
128 learning, help them gain environmental knowledge, and inspire them to social responsibility around
129 sustainability issues. These experiences can help students integrate knowledge and achieve higher-order
130 learning (Easton and Gilburn 2012, Durrant and Hartman 2015) and can reduce achievement gaps
131 correlated with gender and racial identity and socioeconomic status (Beltran et al. 2020). Despite these
132 benefits, field experiences are becoming increasingly limited because of the increasing institutional
133 focus on liability issues and the financial and time requirements for field-experience development
134 (Fleischner et al. 2017). Although the Undergraduate Field Experiences Research Network
135 (<https://ufern.net/>) is increasing field experiences at field and marine stations, these experiences will
136 likely still be out of reach for many students.

137
138 Community-engaged education has similarly received increased emphasis due to the growing awareness
139 that higher education institutions must produce graduates who have the awareness to address pressing
140 social challenges (Hansen et al. 2021). Multiple methods have emerged to increase community
141 engagement for HEI students, including service-learning, community-engaged learning, and community
142 outreach programs (Schatteman 2014), and this engagement has been extended further through the
143 emergence of citizen science (NASEM 2018). These educational efforts build off findings that many
144 students are motivated to help others (Gorski et al. 2015) and community-oriented experiences have
145 been shown to pique students’ interests, enhance learning outcomes, improve retention of female-
146 identifying students in STEM, and lead to more students expressing interest in pursuing service-related
147 career opportunities after college (Tannenbaum and Berrett 2005, Diekman et al. 2015, Mehta et al.
148 2015, Ryan 2017). Although community-engaged education has the potential to be incorporated into
149 STEM education as a complement to content-oriented coursework and on-campus environmental
150 activism, its incorporation into U.S. undergraduate biology education is rare (Zizka et al. 2021, and see
151 below, but see Marx et al. 2021, Nation and Hansen 2021, Yep et al. 2021). Barriers to broader
152 implementation include resources, time, or experience to develop connections with community

153 partners, challenges in obtaining institutional support (Mehta et al. 2015), and frameworks to help
154 students connect theoretical classroom content to application in communities (Zizka et al. 2021).

155
156 Urban agriculture has the potential to expand field-oriented and community-engaged education into
157 undergraduate biology programs in a way that is both practical and impactful, especially for students on
158 urban campuses. Urban agriculture experiences can provide field course experiences on or near
159 campuses (see below), overcoming the time and resources requirements that are significant barriers to
160 implementing field courses that serve large numbers of students. Urban agriculture can also allow for
161 the application and extension of traditional biology theory in diverse sub-disciplines. Finally, urban
162 agriculture is at the core of many community-engagement/service-learning experiences in other
163 disciplines and introducing a “community-oriented” urban agriculture into biology courses should
164 provide new ways for biology departments to help students and faculty connect their activities to social
165 challenges.

166
167 **POTENTIAL RECIPROCAL RELATIONSHIP OF URBAN AGRICULTURE AND UNDERGRADUATE BIOLOGY**
168 **EDUCATION**

169
170 Urban agriculture has rapidly expanded in North America through the development of community
171 gardens and small farms (Fox 2018, Rizzo 2021). Although some commercial urban agriculture has
172 arisen, urban agriculture’s expansion has been driven primarily by an idealism emerging from a variety
173 of social, environmental, and public health benefits (Nogeire-McRae et al. 2018).

174
175 This ideologically based emergence suggests that urban agriculture as a theme can align well with core
176 concepts and competencies highlighted in Vision & Change (Figure 1). First, the topic serves as a
177 connection between two major global trends, the rapid expansion of urbanization (Seto et al. 2011,
178 Elmquist et al. 2019) and the economic and environmental challenges facing global agriculture (Foley et
179 al. 2011; Rockström et al. 2017). Second, urban agriculture makes biology concepts more apparent for
180 students. Production and other crop features are easy-to-visualize outcomes that can make biological
181 concepts, such as adaptation, reproduction, development, productivity, and interactions tangible across
182 various scales of organization. This tangibility can benefit biology majors but may be particularly
183 relevant for non-majors with limited exposure to instruction on the process of science. Third, urban
184 agriculture’s small scale creates opportunities for replication across gardens or plots within gardens,
185 making it well-suited for teaching experimental design, interactions, and systems thinking. Fourth, urban
186 agriculture is practical; sites can be on or close to campus and supplies are relatively inexpensive. Fifth,
187 urban agriculture has many social benefits, including foregrounding indigenous knowledge and
188 agricultural heritages and helping to build connections among diverse communities. And sixth, urban
189 agriculture and more generally food systems as a theme can connect undergraduate biology to chronic
190 disease and other human health challenges that are particularly engaging for the large number of
191 undergraduate biology majors interested in health care as a career. Together, these features of urban
192 agriculture suggest that its use in biology education can engage students by connecting them to local
193 and global challenges that resonate with them.

194
195 Below, we describe the present state of and future opportunities for urban agriculture in undergraduate
196 biology. First, we survey top-rated research and liberal arts colleges to describe whether and how food
197 systems, community engagement, and, more specifically, urban agriculture is currently incorporated
198 into biology curricula. Second, we assess how campus gardens are being used in undergraduate teaching
199 and research to determine the extent to which these gardens could help biologists incorporate urban
200 agriculture into their courses. Third, we present brief case studies focused on biology programs at five

201 universities and colleges to identify opportunities for further incorporation of urban agriculture. We end
202 with some suggestions for future expansion and for overcoming barriers to implementation.

203

204 **URBAN AGRICULTURE IN THE CURRICULUM – CURRENT STATE**

205

206 We used three types of information to assess the current extent to which urban agriculture has been
207 incorporated into undergraduate biology education in the United States: a review of major programs, an
208 assessment using a database from the American Association of Sustainability in Higher Education
209 (AASHE), and case studies from developing programs. Although each assessment type has limitations,
210 collectively they provide information about opportunities and constraints on widespread development of
211 the approach we are highlighting.

212

213 **Current presence of urban agriculture and related themes in major HEI biology programs**

214

215 In October 2021, we surveyed online presentations of Biology or Biology-related programs in 40 top-
216 rated research and liberal arts HEIs to assess the extent to which community-oriented urban agriculture
217 has been incorporated into U.S. biology curricula. We identified HEIs for this survey using U.S. News
218 Reports. Although we are agnostic regarding the educational value of these reports, we focus on them
219 as a way to identify programs that are highlighted for their potential value to prospective students.

220

221 We used publicly available course catalog information from each institution to conduct the survey. We
222 surveyed catalogs to find descriptions of all courses with a BIOL or equivalent course label at each
223 institution. We first sought to identify titles and descriptions for content focused on urban agriculture
224 and related themes. Specifically, we searched for (1) “food”, “agriculture”, or “agro”, (2) “urban”, and (3)
225 “urban agriculture”, and screened all positive returns to determine if courses were associated with
226 human food systems, urban areas, and urban agriculture respectively. Then, we searched for courses
227 that advertised field experiences and community engagement activities – main general benefits of urban
228 agriculture – to determine the extent to which these benefits are already present in undergraduate
229 biology curricula. Specifically, we searched course titles and descriptions for (1) “field” and (2)
230 “community”, “service”, or “experiential” and screened all positive returns to identify courses that
231 advertised field experiences and community engagement activities respectively.

232

233 Our survey reveals several interesting findings about urban agriculture, field biology, and community
234 engagement in undergraduate biology (Table 1, S1A-B). First, food systems and, to a lesser extent, urban
235 systems are represented in biology curricula at top-rated schools, but urban agriculture as a theme is
236 essentially non-existent. On average at the time of our survey, research HEIs offered 2.55 ± 0.72 (mean \pm
237 SE) courses that mentioned food systems-related terms and 0.15 ± 0.11 courses that mentioned urban
238 systems-related terms in course descriptions. Our surveyed liberal arts HEIs offered 1.55 ± 0.43 courses
239 mentioning food systems; one example was BIOL 225 Sustainable Food & Agriculture (Williams College).
240 We also found that 0.35 ± 0.11 course descriptions for our surveyed liberal arts HEIs mentioned urban
241 issues; an example is BIOL 330 Urban Ecology and Evolution (University of Richmond). Only one course
242 in the survey mentioned urban agriculture: BIOEE 4690 - Food, Agriculture, and Society (Cornell).

243

244 Main potential benefits from urban agriculture – field experiences and community-engaged learning –
245 were differentially represented in the survey. Field courses were well-represented in course descriptions
246 for top-rated programs, particularly at research institutions. On average, research HEIs offered $10.5 \pm$
247 2.34 (mean \pm SE) courses that advertised a field component (range 0-34) and liberal arts HEIs offered 5.2 ± 0.66
248 courses (range 0-11). Field courses generally emphasized experience in areas of low human

249 impacts (e.g., field stations, natural preserves). In contrast, courses advertising community engagement
250 opportunities were rare. Only 7 of 20 biology-related programs at research HEIs had any courses
251 mentioning community engagement (mean # courses \pm SE = 0.45 ± 0.17) and only 4 of 20 at liberal arts
252 HEIs mentioned community engagement (mean # courses \pm SE = 0.20 ± 0.09). Examples of biology-
253 related courses mentioning community engagement are BIOL 0371 - Advanced Field Biology: Place-
254 based Global Biology Education (Middlebury) and BIOL 036 Ecology (Swarthmore), which describes
255 "collaboration with local stakeholders and engagement with both Indigenous and Western approaches
256 to understanding humans' connection with the natural world...".
257

258 There are caveats when considering the results of this survey. Instructors may incorporate modules and
259 themes into courses without mentioning them in course descriptions, which are often generic and
260 general to provide flexibility for instructors seeking to deliver dynamic content. In addition, many
261 schools give faculty opportunities to offer "topics courses" that are more experimental and specific.
262 These courses are only reviewed by college- or university-level curriculum committees after several
263 iterations. As a result, our survey is likely missing course content and projects that are related to urban
264 food systems and communities. Most importantly, our survey of "top-rated" schools is not a random
265 sample of U.S. HEIs and thus unlikely represents accurately the challenges facing undergraduate biology
266 education nor the extent to which creative solutions are emerging to address those challenges. In
267 particular, the presence of field experiences in pristine locations are likely over-represented in well-
268 resourced schools given the costs of these experiences. In addition, it is possible that "urban" as a
269 theme is under-represented in top-rated liberal arts colleges in particular given that many of these
270 schools are in non-urban settings.
271

272 Regardless, we draw several conclusions from these results. First, food systems and urbanization as
273 themes are not common in undergraduate biology curricula, at least in our surveyed institutions. There
274 are several reasons for this scarcity, including that these themes may be well represented in other
275 departments or schools at the institution. Regardless, this rarity suggests that undergraduate biology
276 has the opportunity to adjust curricular offerings to help students address pressing global challenges.
277 Second, urban agriculture as a theme is essentially non-existent in biology programs at top-rated
278 schools. Finally, field experiences, a main potential benefit of urban agriculture, are fairly common, but
279 it is unclear how widespread and costly these experiences currently are. Another main benefit of urban
280 agriculture for biology – community engagement – is very rare in these programs. Together, these
281 results suggest that there is significant opportunity for expansion of urban agriculture and related
282 themes in undergraduate biology.
283

284 **Campus gardens in undergraduate biology education?**

285 Another source of information about urban agriculture in biology education is assessing the extent to
286 which campus gardens are incorporated into biology curricula. Food gardens on HEI campuses have
287 become much more common over the past few decades, and research has shown that they can provide
288 diverse benefits to students, faculty, institutions, and surrounding communities (Marsh et al. 2020). For
289 students and faculty, campus gardens can provide field-based teaching and research opportunities
290 across diverse disciplines (Scoggins 2010, and see our review below), contribute positively to student
291 mental health (Cupples and Finewood 2018), and increase student access to organic foods (Ullevig et al.
292 2020). For institutions, campus gardens are often part of sustainability plans and are used in recruitment
293 and outreach efforts to prospective students and donors (Duram and Klein 2015, Duram and Williams
294 2015, Laylock Pederson and Robinson 2018). For communities, campus gardens can support outreach
295 events (Anderson et al. 2018) and inspire students to become involved in service activities.
296

297 Here, we compiled data from the Association for the Advancement of Sustainability in Higher Education
298 (AASHE) Sustainability Tracking and Rating System (STARS) database (<https://stars.aashe.org>) to
299 determine the extent to which U.S. HEIs have campus gardens and how commonly gardens are
300 incorporated into teaching and research in biology and related disciplines. Although several case studies
301 have examined impacts of campus gardens on student engagement, experiential learning, and campus
302 sustainability, there is scant research on the extent to which gardens are incorporated into educational
303 programming in the U.S. HEIs in general. One example is Duram and Klein (2015), which surveyed 52
304 campus gardens in the U.S. and found that 92% of garden manager respondents cited “education” as
305 the primary goal of the garden and indicated that course experiences were primarily in the areas of
306 sustainability and environmental studies. To our knowledge, there is no information about incorporation
307 of campus gardens into biology-related programs.

308
309 We included in our survey results from 286 institutions of higher education that submitted AASHE
310 reports in 2019. We compiled information on campus gardens or farms from several sections of the
311 report (Table S2). For all institutions that reported having a campus garden or farm, we searched the
312 descriptions in the other fields in Table S2 for (1) any explicit mention of using campus gardens/farms in
313 formal undergraduate or graduate classes, and (2) any explicit mention of using campus gardens/farms
314 for research. Class-integrated research projects were counted in both categories. We also searched
315 websites of campus gardens/farms reported in the STARS report for any explicit mention of use by
316 courses or research. Where specific courses were listed, we categorized those courses as either Biology,
317 Environmental Studies/ Sustainability, Horticulture, Nutrition, or Other. We then determined the
318 percentage of institutions from each institution type (Associate, Baccalaureate, Master,
319 Doctoral/Research) that reported having a campus garden or farm project, the percentage of those
320 institutions (of each institution type) that reported (either in the STARS report or on the website) using
321 the project in teaching or in research, and the courses listed as using the project.

322
323 Almost all institutions in the STARS database reported that they were associated with some type of
324 garden or farm. In response to the question “*Does the institution have gardens, farms, community*
325 *supported agriculture (CSA) or fishery programs, and/or urban agriculture projects where students are*
326 *able to gain experience in organic agriculture and sustainable food systems?*”, 270 of 286 institutions
327 (94%) answered “yes”. Almost all institutions responded positively regardless of institution type
328 (Associate college: 11/12 (92%), Baccalaureate: 73/75 (97%), Masters: 65/72 (90%), Doctoral/Research:
329 119/125 (95%), Other: 2/2 (100%)).

330
331 Of the HEIs that reported having agriculture- or urban agriculture-related projects, we found that many
332 (119/270 = 44%) indicated that projects were used for teaching or research. Percentage use in teaching
333 or research did not differ significantly across institution type (Associate college: 5/12 (45%),
334 Baccalaureate: 38/73 (52%), Masters: 30/65 (46%), Doctoral/Research: 46/119 (46%), Other: 0/2 (0%)).
335 For HEIs that listed specific courses using campus gardens/farms, we found that the majority of courses
336 were in either Environmental Studies or Sustainability (52%), and 26% were in Biology. Together, these
337 results indicate that many HEIs in the U.S. have urban agriculture-type projects but less than 10% of all
338 institutions reporting these projects indicated that the projects were used in Biology courses.

339
340 It is important to note that institutions completing AASHE STARS reports likely disproportionately invest in
341 sustainability-related projects, suggesting that the true number of U.S. HEIs with urban agriculture-type
342 projects and the extent to which biology courses are connected to such projects is likely less than
343 reported here. Also, the most relevant STARS report question asks only if teaching OR research is

344 connected to urban agriculture-type projects, making it difficult to assess precisely how such projects
345 are connected to the curriculum.

346
347 Regardless of these caveats, these results suggest that urban agriculture-related projects are very
348 common at HEIs and there is significant opportunity for expanding their use in undergraduate biology
349 education.

350
351 **Case studies**
352

353 Our case studies provide additional context and ideas about how urban agriculture might be
354 incorporated into undergraduate biology. We focus on five institutions represented by the authors –
355 University of St. Thomas (MN), Tulane University (LA), Salish Kootenai College (MT), University of San
356 Diego (CA), and Rollins College (FL). These institutions were first identified because of their involvement
357 in the Ashoka Changemaker Campus network, an international effort that brings together institutions
358 committed to connecting higher education to community engagement and social innovation. These
359 institutions have also partnered to develop a Research Collaboration Network sponsored by the
360 Undergraduate Biology Education program of the National Science Foundation (NSF-UBE).

361
362 **Institution:** University of St. Thomas (UST) – Biology Department
363 *Institutional overview*

364 The UST Biology department offers 2 lower-division and 3 upper-division elective courses focused on
365 food systems. Of the lower-division courses, BIOL 209 Biology of Sustainability is a major-required core
366 course with a 3-week unit focused on global agricultural challenges, and BIOL 296 Future of Food is an
367 elective 2-credit seminar focused on readings and discussions about current innovations and constraints
368 on food production, distribution, and consumption. Part of the seminar includes site visits and guest
369 lectures by local practitioners. Of the upper-division elective courses, BIOL 315 Plants, Food, and
370 Medicine is a modified plant physiology course that has incorporated sustainable food production as a
371 theme. BIOL 490 Sustainable Food Systems is a senior seminar capstone that includes semester-long
372 small-group projects completed in collaboration with a variety of community partners. Examples of
373 student-led projects include an investigation of food insecurity on and off campus and an assessment of
374 perceptions of conservation agriculture in rural communities using interviews and surveys. BIOL 498
375 Urban Agriculture and Social Innovation in Cape Town, South Africa is a study abroad course that
376 focuses on ecology-oriented student projects completed with farmers in community gardens in the
377 Khayelitsha township. Activities in this course are coordinated with Abalimi Bezakhaya
378 (abalimbizakhaya.org.za), a non-profit micro-farming organization focused on assisting impoverished
379 groups and communities in the Greater Cape Town area.

380
381 *Biology co-curriculum related to urban agriculture*

382 The emergence of food systems-related curriculum has coincided with the development of an on-
383 campus community garden project, the UST Stewardship Garden (Figure 2). This project was developed
384 in 2010 to combine undergraduate-driven research, teaching, and community engagement around the
385 theme of urban agriculture. The SG consists of community-garden-style plots embedded in an on-
386 campus gathering space. As a research resource, the SG has supported the work of over 50
387 undergraduate and high school researchers on questions relevant to local agriculture communities and
388 the broader fields of ecology and environmental science. Data from the site have contributed to 8 peer-
389 reviewed science publications with undergraduate authors and a major research grant from the National
390 Science Foundation (NSF). Examples of projects include evaluating alternative composting processes
391 (Small et al. 2017) and quantifying nutrient loss and recovery from different fertilization and planting

392 strategies (Shrestha et al. 2020). As a teaching resource, the SG has provided tangible and accessible
393 opportunities for developing core STEM competencies, including systems thinking, engaging broadly
394 with the scientific process, and linking science to society (Figure 1), through experiences in non-majors,
395 core, and upper-division courses, while helping students make connections between STEM, the liberal
396 arts, and social/environmental challenges. These educational benefits led to the development of the
397 NSF-UBE network. Finally, as a community engagement resource, the SG site has: produced ~2,000 lbs of
398 produce donations each year; hosted workshops and other gatherings with campus members and the
399 general public; and spawned a non-profit (BrightSide Produce) that distributes fruits and vegetables to
400 corner stores in underserved urban neighborhoods.

401

402 *Opportunities for growth at St Thomas*

403 Connecting activities in the Biology Department to the thriving local food system movement in the Twin
404 Cities could enhance student experiences in the courses listed above and other existing classes.
405 Providing more opportunities for long-term relationship building with community members could help
406 students build empathy and understanding. Expanding international experiences like BIOL 498 Urban
407 Agriculture and Social Innovation in Cape Town, South Africa would provide students with opportunities
408 to connect to marginalized communities in more authentic and less transactional experiences.
409 Opportunities also exist for collaborating with other disciplines within the institution to create more
410 impactful projects.

411

412 **Institution:** Tulane University – Ecology and Evolutionary Biology (EEB)

413 *Institutional overview*

414 The primary campus of Tulane is located in uptown New Orleans and occupies 130 acres. Tulane is well-
415 known for its investment in community engagement and service learning and students provide more
416 than 750,000 hours of community service each year.

417

418 *Biology curriculum related to urban agriculture*

419 Tulane's Ecology and Evolutionary Biology (EEB) Department has 5 major courses with a connection to
420 food systems: 1) EBIO 2210: Insect and Human Interaction has a module in which students study insect
421 behavior and interactions in urban gardens. 2) EBIO 3180: Plants and Human Affairs focuses on the
422 interaction between humans and plants with an emphasis on food security in New Orleans and globally.
423 Community gardens are used in plant propagation projects. This course attracts students from different
424 disciplines including business and political science students. Goals for this class are to engage such
425 students to work on collaborative, interdisciplinary projects with community organizations addressing
426 food insecurity in New Orleans. 3) EBIO 3590: Plant Biology and Adaptation uses an urban garden to
427 study plant growth, propagations, and plant-insect interactions. 4) In EBIO 4430: Entomology, students
428 use local settings to design experiments to study vegetable and ornamental plant pests. Finally, 5) EBIO
429 4600 Urban Agroecology and Sustainability in New Orleans is a project-centered course in which
430 students evaluate ecological interactions and use their knowledge to increase produce productivity in
431 urban gardens.

432

433 *Biology co-curriculum related to urban agriculture*

434 Through service-learning, Tulane has developed gardens in two neighborhoods in the city. The service-
435 learning courses are optional components in some EEB courses. Two gardens have been developed in
436 partnership with the Mardi Gras Indians Chiefs Council and New Zion Baptist Church, and two others
437 have been developed in the Broadmoor neighborhood through a partnership with the Broadmoor
438 Improvement Association.

439

440 *Opportunities at Tulane*

441 Developing an on-campus community garden to complement Tulane's off-campus urban agriculture
442 would create opportunities for conversations among Tulane community members about fresh produce
443 access and increase opportunities for interdisciplinary collaboration (with Economics, Sociology, and
444 other disciplines).

445

446 **Institution:** Salish Kootenai College – Biology

447 *Institutional overview*

448 Salish Kootenai College (SKC) is a Tribal College chartered by the Confederated Salish and Kootenai
449 Tribes. The campus is 72 acres and located on the rural Flathead reservation in Montana. SKC serves
450 about 700 students representing 68 North American Tribes, and 68% of the students are first generation
451 college students.

452

453 *Biology (Life Sciences) curriculum related to urban agriculture*

454 SKC Life Sciences department is the only 4-year biomedically-oriented Life Sciences program at a tribal
455 college nationwide. A majority of students taking biology courses have an interest in a career in
456 healthcare such as nursing. The department offers Cellular Biology and Environmental Health tracks.
457 Courses include biology standards (e.g., Cellular Biology, Genetics, Bioinformatics) with some specific
458 environmental health offerings (Virology, One Health, Environmental Toxicology). Currently no courses
459 are specifically linked to urban agriculture or, more generally, to food systems or urbanization.

460

461 *Biology (Life Sciences) co-curriculum related to urban agriculture*

462 Currently, SKC has a community greenhouse and garden, both part of the SKC extension initiative. The
463 maintenance is done by volunteers, both students and community members, and students with paid
464 positions. The extension initiative is mainly funded through federal grants from the U.S. Department of
465 Agriculture (USDA), National Science Foundation (NSF), and National Institute of Health (NIH-INBRE).
466 Each Fall, the community garden runs a 10-week sustainable diet program in which 40 community
467 members can enroll for curriculum on sustainable healthy diets.

468

469 *Opportunities for growth at SKC*

470 Integration of the community garden in Life Sciences program could create opportunities for cross talk
471 between classes spanning the curriculum. The community garden could also create entrepreneurship
472 experiences and a closer collaboration with the SKC Business department. Finally, there is untapped
473 opportunity for involvement of Life Sciences faculty and students with the 10-week sustainable diet SKC
474 extension program to include biomedical research on health disparities in Native American
475 communities.

476

477 **Institution:** University of San Diego - Biology

478 *Institutional overview*

479 USD is a comprehensive Catholic university with approximately 9000 students. It is situated in a diverse
480 urban community less than 20 miles from an international border (Mexico). The student body comprises
481 37% minority and 9% international students. Community service and changemaking are institutional
482 priorities.

483

484 *Biology curriculum related to urban agriculture*

485 The Biology Department at USD emphasizes undergraduate research, requiring every student to engage
486 in an independent research project with a USD faculty mentor, a course-based research experience, or
487 an off-campus research internship. Students in BIOL 240 Bioenergetics and Systems (approximately 170-

488 190 students per semester) conduct greenhouse experiments to compare effects of commercial vs
489 organic fertilizer on tomato plant growth and physiology. Students in BIOL 472 Plant Physiology conduct
490 a variety of experiments with agricultural crop species, including plant cell culture for producing clonal
491 lines, plant responses to herbivory, and plant growth regulators. Typically, at least one section annually
492 of BIOL 309 Research Methods uses agricultural crop species as the experimental system. Finally,
493 students in BIOL 113 Plants and People for non-majors conduct experiments with commercial crop
494 species, visit Wild Willow Farms (a local urban educational agriculture facility), and engage in community
495 service-learning activities in school gardens at a local middle school.
496

497 *Biology co-curriculum related to urban agriculture*

498 USD has a community garden established and maintained by student volunteers. Currently, there are no
499 connections between the biology curriculum (or any other curriculum) and the student garden.
500

501 *Opportunities for growth at USD*

502 Enhancing the framework of sustainable agriculture and healthy food systems to introductory courses
503 would allow biology students to integrate biology, social justice, sustainability, and climate change more
504 explicitly. Converting the BIOL 240 Bioenergetics and Systems tomato plant experiment from a
505 greenhouse to a community garden project could create a more expansive and integrative learning
506 experience and help to the ecological and human health benefits of urban gardening. In particular,
507 leveraging the health benefits of urban gardening would promote more buy-in from students interested
508 in health professions. Conducting biology research in the community garden could serve a large number
509 of summer research students or those engaged in a course-based research project. Other opportunities
510 include connecting biology experiences in urban agriculture to living-learning community (LLC) initiatives
511 that integrate social and academic experiences around themes such as Advocate, Cultivate, and
512 Innovate. Finally, expanding the exploration of urban agriculture and links to diet impacts on health,
513 food security issues, and environmental sustainability are potentially fruitful ways to connect the biology
514 curriculum to changemaking and community engagement - a central part of the USD mission.
515

516 **Institution:** Rollins College - Biology

517 *Institutional overview*

518 Rollins College is a co-educational liberal arts college just north of Orlando, FL. It has approximately 3300
519 students. The institution website emphasizes that students will be able to "connect [their] education
520 and ... passions to the needs of the world".
521

522 *Biology curriculum and co-curriculum related to urban agriculture*

523 The Biology Department is exploring potential connections to urban agriculture on campus and in the
524 community. Rollins has a campus garden "the Urban Farm" that grew over the last five years from a
525 student endeavor to a collaborative effort among students, faculty, and staff. This garden is now central
526 to a Sustainable Agriculture course offered through Environmental Studies. Biology is collaborating with
527 Rollins' Social Impact Hub, a creative space for human-centered design thinking, to build connections
528 with urban agriculture organizations in Orlando. These organizations include Infinite Zion Farms (Figure
529 3), which establishes farms in the Parramore neighborhood of Orlando and elsewhere as an affordable
530 source of organic produce and education to the community, and 4roots, a community alliance seeking to
531 build a sustainable food system.
532

533 *Opportunities for growth at Rollins*

534 For Rollins, key next steps involve more fully integrating the Urban Farm work into the Biology major,
535 both in plant biology and ecology. Collaborations with the campus food service are underway to

536 determine which crops, during which season, are most likely to enhance the value of the joint effort to
537 bring campus grown food to students' tables. Further, comparative experiments in hydroponic
538 gardening between the Rollins' Urban Farm and Infinite Zion Farms are about to be launched. The
539 opening of a new research greenhouse on the campus freed up a hoop house greenhouse adjoining the
540 Urban Farm that will extend the gardening season into the brief winter months in Florida.

541

542 **NEXT STEPS AND GENERAL DISCUSSION**

543

544 Our review suggests urban agriculture is rarely incorporated into undergraduate biology education, but
545 there are significant opportunities for doing so that could enhance educational offerings. Our review of
546 major programs found that although some biology-related programs have courses focused on food
547 systems and urban challenges, these courses are rare and only one mentions urban agriculture. In a
548 survey of the AASHE STARS database, we found that a potential tool for urban agriculture, campus
549 gardens, are common in U.S. HEIs, but few seem to be used in undergraduate biology courses. Our case
550 studies of 5 HEIs engaging with this issue highlight innovative curricular and co-curricular programming,
551 but each identifies significant opportunities for further implementation. Together this work suggests
552 that incorporating urban agriculture into undergraduate biology can help programs develop field and
553 community engagement experiences, facilitating the implementation of Vision & Change
554 recommendations.

555

556 Implementation of pedagogical innovations often faces significant barriers due to several factors
557 including time limitations (e.g., for developing curricula and community partnerships), lack of
558 professional rewards, and other logistical constraints on instructors. Here we make four
559 recommendations for how to incorporate urban agriculture into biology curricula with an eye toward
560 these barriers.

561

562 First, we recommend, where possible, building, developing, and using campus gardens for biology
563 courses. We found that 94% of HEIs submitting AASHE STARS reports had campus gardens but few
564 reported using them in biology courses. Incorporating these gardens into courses could help lab
565 instructors create inquiry-based research experiences for large numbers of students, a central
566 recommendation in the Vision and Change document. Linking biology courses to campus gardens could
567 also have diverse benefits for the garden and the broader community. Although campus gardens have
568 the potential to provide many social and environmental benefits, some gardens fail or fall into disuse
569 (Marsh et al. 2020). Main constraints include lack of staffing, consistent student support, and
570 institutional financing. Creating biology labs and research projects based in a campus garden could help
571 justify re-allocation of departmental and college support from more traditional labs to the garden.

572

573 Second, we recommend that biology faculty develop research programs in urban agriculture and
574 connect these programs to courses. Research-based and student-centered instruction can help
575 transform education away from fact memorization and toward the development of skills for scientific
576 inquiry and collaborative work (AAAS 2011). Although the use of research-based instruction is increasing
577 in undergraduate life sciences education, many courses still rely primarily on lectures and exams focused
578 on memorization of disciplinary content (AAAS 2019). A promising approach to engage a large number
579 and more diverse range of students in research is through course-based undergraduate research
580 experiences (CURE) (Auchincloss et al., 2014, Elgin et al., 2016, Hernandez et al. 2021). If faculty can
581 initiate CUREs that align with their existing research efforts, it can allow them to benefit from reward
582 structures that encourage research productivity (Smith et al. 2021). There are many opportunities for
583 impactful research on applied urban agriculture and urban agroecology that can connect scholars, urban

584 growers, and communities in mutually beneficial partnerships (Nicklay et al. 2020). In addition, urban
585 agriculture can provide equally valuable opportunities for basic research on central topics in ecology,
586 including biodiversity, biogeochemical cycling, abiotic controls on production, and human-mediated
587 feedbacks.

588
589 Third, we recommend that biology educators work with community engagement experts to build
590 collaborations with community groups working in the local food system. Community engagement offices
591 are becoming more common in HEIs, a movement inspired by a growing awareness that students are
592 motivated by helping others. Benefits of community engaged learning that go beyond developing
593 scientific competencies include improving student's communication, critical thinking, and writing skills
594 (Astin et al. 2000, Eyler and Giles 1999, Gallini and Moely 2003, Vogelgesang, and Astin 2000). Further,
595 community engaged learning gives students an opportunity to work with people from diverse
596 backgrounds and gain experience with conflict resolution (Moely et al. 2002, Simons and Cleary 2006).
597 Finally, community engaged learning helps students feel connected to their community and take
598 responsibility in addressing social justice issues (Munter 2002). As a first step in developing curriculum
599 that centers community engagement, biology educators could engage with the Science Education for
600 New Civic Engagements and Responsibilities (SENCER) program, which helps faculty develop courses
601 connected to real-world challenges. Assessments have found that civic engagement emphasized in
602 SENCER has increased student academic confidence and interest in science. Further engagement could
603 involve faculty connecting courses to urban agriculture organizations that are active in most U.S. cities.
604 Organizations such as Infinite Zion Farms in Orlando are interested in deepening relationships with
605 university partners. If done with care, these partnerships could provide impactful learning experiences
606 for students while providing resources and connections for partner organizations. University support for
607 community urban agriculture projects could help expand urban food production and increase urban
608 food system resilience in a time of increasing uncertainty (Yan et al. 2022).
609

610 Creating effective, reciprocal relationships between academia and community organizations requires
611 careful planning (Jordaan and Mennega 2021). Academics engaging in these partnerships should ensure
612 that collaborations benefit rather than burden community partners (Bringle and Hatcher 2002).
613 Situating community partners as co-educators, for example, gives community members an opportunity
614 to share their expertise with students to enhance their learning (for a more extensive discussion of this
615 important issue, see Jordaan and Mennega 2021). On-campus community engagement offices can be
616 useful for helping to best navigate these and other potential challenges.
617

618 Finally, we recommend university personnel and community partners connect to networks for
619 developing and sharing curricular ideas, creating cross-site experiments, and connecting courses to
620 community engagement. One opportunity is through our newly formed Training Undergraduate
621 Biologists using urban Agriculture (TUBA) network. (www.tuba-rcn.org)
622

623 Undergraduate biology education needs to increase engagement for diverse student audiences to
624 reduce attrition and in turn help generate scholars and professionals ready to address the complex
625 challenges associated with rapid global change and growing social inequalities. Urban agriculture as a
626 theme could increase student engagement with biology education by highlighting pressing
627 contemporary challenges, increasing opportunities for local field experiences, and creating new
628 relationships with community organizations. Implementing our recommendations could help urban
629 agriculture become common in undergraduate biology. If done with care, this integration could help
630 students make positive community contributions within the context of required coursework, and help
631 instructors feel a greater sense of accomplishment in this era of change and uncertainty.

632

633 **References**

634

635 American Association for the Advancement of Science. (2011). Vision and change in undergraduate
636 biology education: A call to action. Washington, DC.

637 Anderson, C., Maher, J., & Wright, H. (2018). Building sustainable university-based community gardens:
638 Volunteer perceptions of enablers and barriers to engagement and benefits received from
639 volunteering in the Moving Feast. *Cogent Soc. Sci.* 2018, 4, 1–19

640 Astin, A.W., Vogelgesang, L.J., Ikeda, E.K., & Yee, J.A. (2000). *How service learning affects students*. Los
641 Angeles, CA: Higher Education Research Institute.

642 Auchincloss, L.C., Laursen, S.L., Branchaw, J.L., Eagan, K., Graham, M., Hanauer, D.I., Lawrie, G., McLinn
643 C., Pelaez, N., Rowland, S., Towns, M., Trautmann, N.M., Varma-Nelson, P., Weston, T.J., & Dolan, E.L.
644 (2014). Assessment of course-based undergraduate research experiences: a meeting report. *CBE-Life
645 Sciences Education* 13(1):29–40.

646 Banger, G. & Brownell, S. (2014). Course-based undergraduate research experiences can make scientific
647 research more inclusive. *CBE-Life Sciences Education* 13(4):602-606.

648 Beltran, R.S., Marnocha, E., Race, A., Croll, D.A., Dayton, G.H., & Zavaleta, E.S. (2020). Field courses
649 narrow demographic achievement gaps in ecology and evolutionary biology. *Ecology and Evolution*
650 10:5184-5196.

651 Bringle, R.G., & Hatcher, J.A. (2002). Campus-community partnerships: The terms of engagement.
652 *Journal of Social Issues* 58(3):503-516.

653 Chen, X. (2013). *STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001)*.
654 National Center for Education Statistics, Institute of Education Sciences, U.S. Department of
655 Education.

656 Chen, Y., Johri, A., & Rangwala, H. (2018). Running out of STEM: a comparative study across STEM
657 majors of college students at-risk of dropping out early. *Proceedings of the 8th International
658 Conference on Learning Analytics and Knowledge*. pp. 270–279.

659 Cupples, C.C., & Finewood, M.H. (2018). Benefits of college farms & gardens: Gardens and farms on
660 campus boost student health and strengthen academic programs. *Today's Dietitian* 20: 20–24.

661 Diekman, A.B., Weisgram, E.S., & Belanger, A.L. (2015). New routes to recruiting and retaining women in
662 STEM: policy implications of a communal goal congruity perspective. *Social Issues and Policy Review*
663 9(1):52–88.

664 Duram, L.A., & Klein, S.K. (2015). University food gardens: A unifying place for higher education
665 sustainability. *International Journal of Innovation and Sustainable Development* 9(3/4): 282-302.

666 Duram, L.A., & Williams, L.L. (2015). Growing a student organic garden within the context of university
667 sustainability initiatives. *International Journal of Sustainability in Higher Education* 16(1):3-15

668 Durrant, K.L., & Hartman, T.P.V. (2015) The integrative learning value of field courses. *Journal of
669 Biological Education* 49(4): 385-400

670 Easton, E., & Gilburn, A.S. (2012). The field course effect: Gains in cognitive learning in undergraduate
671 biology students following a field course. *Journal of Biological Education* 46(1):29-35.
672 DOI:10.1080/00219266.2011.568063

673 Elgin, S., Bangera, G., Decatur, S., Dolan, E., Guertin, L., Newstetter, W., Juan, E., Smith, M., Weaver, G.,
674 Wessler, S., Brenner, K., & Labov, J. (2016). Insights from a convocation: Integrating discovery-based
675 research into the undergraduate curriculum. *Cell Biology Education*. 15. fe2-fe2. 10.1187/cbe.16-03-
676 0118.

677 Elmqvist, T. Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., &
678 Folke, C. (2019) Sustainability and resilience for transformation in the urban century. *Nature
679 Sustainability* 2:267–273.

680 Estrada, M., Burnett, M., Campbell, A.G., Campbell, P.B., Denetclaw, W.F., Gutiérrez, C.G., Hurtado, S.,
681 John, G.H., Matsui, J., McGee, R., Okpodu, C.M., Robinson, T.J., Summers, M.F., Werner-Washburne,
682 M., & Zavala, M. (2016). Improving underrepresented minority student persistence in STEM. *CBE-Life
683 Sciences Education* 15:es5, 1–10

684 Eyler J, & Giles Jr. DE (1999) *Where's the learning in service-learning?* San Francisco, CA: Jossey-Bass.

685 Fleischner, T.L., Espinoza, R.E., Gerrish, G.A., Greene, H.W., Kimmerer, R.W., Lacey, E.A., Pace, S., Parrish,
686 J.K., Swain, H.M., Trombulak, S.C., Weisberg, S., Winkler, D.W., & Zander, L. (2017). Teaching biology
687 in the field: Importance, challenges, and solutions. *BioScience* 67:558–567

688 Jonathan A. Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller,
689 N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda,
690 C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D., & Zaks, D.P.M. (2011). Solutions for a
691 cultivated planet. *Nature* 478:337–342

692 Fox, T.J. (2018). *Urban Farming: Sustainable City Living in Your Backyard, in Your Community, and in the
693 World.* Fox Chapel Publishing Company, Mount Joy, Pennsylvania

694 Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014)
695 Active learning increases student performance in science, engineering, and mathematics.
696 Proceedings of the National Academy of Sciences, U S A. 111(23):8410-8415. doi:
697 10.1073/pnas.1319030111.

698 Gallini, S.M., & Moely, B.E. (2003). Service-learning and engagement, academic challenge, and retention.
699 *Michigan Journal of Community Service Learning* 10: 5-14.

700 Gorski, I., Obeysekare, E., Yarnal, C., & Mehta, K. (2015). Responsible engagement: building a culture of
701 concern. *Journal of Community Engaged Scholarship* 8(2):1e12.

702 Haak, D.C., HilleRisLambers, J., Pitre, E., Freeman, S. (2011) Increased structure and active learning
703 reduce the achievement gap in introductory biology. *Science* 332: 1213–1216.

704 Hansen, A.K., Connors, P.K., Donnelly-Hermosillo, D., Full, R., Hove, A., Lanier, H., Lent, D., Nation, J.,
705 Tucker, K.P., Ward, J., Whitenack, L., & Zavaleta, E. (2021). Biology beyond the classroom:
706 Experiential learning through authentic research, design, and community engagement. *Integrative
707 and Comparative Biology* 61: 926-933

708 Hernandez, T., Donnelly-Hermosillo, D.F., Person, E., & Hansen, A.K. (2021). "At least we could give our
709 input": underrepresented student narratives on conventional and guided inquiry-based laboratory
710 approaches. *Integrative and Comparative Biology* 61: 992–1001

711 Intemann, K. (2009). Why diversity matters: understanding and applying the diversity component of the
712 National Science Foundation's broader impacts criterion. *Social Epistemology* 23(3-4):249–266.

713 Jordaan, M., & Mennega, N. (2021). Community partners' experiences of higher education service-
714 learning in a community engagement module. *Journal of Applied Research in Higher Education*

715 Laursen, S. (2019). *Levers for Change: An Assessment of Progress on Changing STEM Instruction.*
716 American Association for the Advancement of Science.

717 Laycock Pedersen, R., & Robinson, Z.P. (2018). Reviewing university community gardens for
718 sustainability: Taking stock, comparisons with urban community gardens and mapping research
719 opportunities. *Local Environment* 23(1): 652–671.

720 Marsh, P., Mallick, S., Flies, E., Jones, P., Pearson, S., Koolhof, I., Byrne, J., & Kendal, D. (2020). Trust,
721 connection and equity: Can understanding context help to establish successful campus community
722 gardens? *International Journal of Environmental Research and Public Health* 17: 7476

723 Marx, M.A., Glaser, R.L., Moran, C.E., Tucker, K.P. (2021). A creative model for an interdisciplinary
724 approach to service-learning. *Integrative and Comparative Biology* 61: 1028–1038

725 Mehta, K., Gorski, I., Liu, C., Weinstein, S., Brua, C., & Christensen, A. (2015). Expanding engagement
726 opportunities at a large land-grant research university: the engagement ecosystem model. *Journal of
727 Community Engaged Scholarship* 8(2):44e58.

728 Moely, B.E., McFarland, M., Miron, D., Mercer, S., & Ilustre, V. (2002). Changes in college students'
 729 attitudes and intentions for civic involvement as a function of service-learning experiences. *Michigan*
 730 *Journal of Community Service Learning* 9:18-26.

731 Munter, J. (2002). Linking community and classroom in higher education: Service-learning and student
 732 empowerment. *Journal of Nonprofit & Public Sector Marketing* 10:151-164.

733 Nation, J.M., & Hansen, A.K. (2021). Perspectives on community STEM: Learning from partnerships
 734 between scientists, researchers, and youth. *Integrative and Comparative Biology* 61:1055–1065.

735 National Academies of Sciences, Engineering, and Medicine. 2018. *Learning Through Citizen Science:
 736 Enhancing Opportunities by Design*. Washington, DC: The National Academies Press

737 Nguyen, K.A., Borrego, M., Finelli, C.J., DeMonbrun, M., Crockett, C., Tharayil, S., Shekhar, P., Waters, C.,
 738 & Rosenberg, R. (2021). Instructor strategies to aid implementation of active learning: a systematic
 739 literature review. *International Journal of STEM Education* 8:9

740 Nicklay, J.A., Cadieux, K.V., Rogers, M.A., Jelinski, N.A. LaBine, K., & Small, G.E. (2020). Facilitating spaces
 741 of urban agroecology: A learning framework for community-university partnerships. *Frontiers in
 742 Sustainable Food Systems* 4:143

743 Nogeire-McRae, T., Ryan, E.P., Jablonski, B.B.R., Carolan, M., Arathi, H.S., Brown, C.S., Saki, H.H.,
 744 McKeen, S., Lapansky, E., & Schipanski, M.E. (2018). The role of urban agriculture in a secure,
 745 healthy, and sustainable food system. *BioScience* 68: 748-759.

746 Odom, S., Boso, H., Bowling, S., Brownell, S., Cotner, S., Creech, C., Drake, A.G., Eddy, S., Fagbodun, S.,
 747 Hebert, S., James, A.C., Just, J., St Juliana, J.R., Shuster, M., Thompson, S.K., Whittington, R., Wills,
 748 B.D., Wilson, A.E., Zamudio, K.R., Zhong, M., & Ballen, C.J. (2021). Meta-analysis of Gender
 749 Performance Gaps in Undergraduate Natural Science Courses. *CBE-Life Sciences Education* 20: ar40

750 PCAST STEM Undergraduate Working Group (2012) Engage to Excel: Producing One Million Additional
 751 College Graduates with Degrees in Science, Technology, Engineering, and Mathematics, eds Gates SJ,
 752 Jr, Handelsman J, Lepage GP, Mirkin C (Office of the President, Washington).

753 Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., DeClerck, F.,
 754 Shah, M., Steduto, P., de Fraiture, C., Hatibu, N., Unver, O., Bird, J., Sibanda, L., & Smith, J. (2017).
 755 Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio* 46:4–
 756 17. <https://doi.org/10.1007/s13280-016-0793-6>

757 Ryan, R.G. (2017). Social and cognitive outcomes of service learning: results from pre-post and control
 758 group comparison. *Journal of Community Engaged Scholarship* 9(3):19e34

759 Rizzo, V. ed. (2021). *Urban farmers: The now (and how) of growing food in the city*. Gestalten, Berlin.

760 Schatteman, A.M. (2014). Academics meets action: community engagement motivations, benefits, and
 761 constraints. *Journal of Community Engaged Scholarship* 6(1):17e30.

762 Scoggins, H.L. (2010). University garden stakeholders: Student, industry, and community connections.
 763 *HortTechnology* 20:528–529.

764 Seto, K.C., Fragkias, M., Güneralp, B., & Reilly, M.K. (2011). A meta-analysis of global urban land
 765 expansion. *PLoS One* 6:e23777.

766 Seymour, E. & Hunter, A-B. (2019). *Talking about Leaving Revisited: Persistence, Relocation, and Loss in
 767 Undergraduate STEM Education*. Switzerland: Springer.

768 Shrestha P., Small G.E. & Kay A. (2020). Quantifying nutrient recovery efficiency and loss from compost-
 769 based urban agriculture. *PLoS ONE* 15:e0230996.

770 Simons, L., & Cleary, B. (2006). The influence of service learning on students' personal and social
 771 development. *College Teaching* 54:307-319.

772 Singer, S.R., Nielsen, N.R., & Schweingruber, H.A. (2012). *Discipline-based Education Research:
 773 Understanding and Improving Learning in Undergraduate Science and Education*. Washington, DC:
 774 National Academies Press.

775 Small G., Sisombath B., Reuss L., Henry R. & Kay A.D. (2017). Assessing how the ratio of food waste to
776 wood chips in compost affects rates of microbial processing and subsequent vegetable yield.
777 *Compost Science & Utilization* 25:272-281.

778 Smith, T., Broder, E.D., Tinghitella, R.M., & Ingle, S.J. (2021). Using inter-institutional collaboration to
779 generate publishable findings through course-based undergraduate research experiences. *The
780 American Biology Teacher* 83(7):451-457.

781 Stains, M., Harshman, J., Barker, M.K., Chasteen, S.V., Cole, R., DeChenne-Peters, S.E., Eagan, Jr. M.K.,
782 Esson, J.M., Knight, J.K., Laski, F.A., Levis-Fitzgerald, M., Lee, C.J., Lo, S.M., McDonnell, L.M., McKay,
783 T.A., Michelotti, N., Musgrave, A., Palmer, M.S., Plank, K.M., Rodela, T.M., Sanders, E.R., Schimpf,
784 N.G., Schulte, P.M., Smith, M.K., Stetzer, M., Van Valkenburgh, B., Vinson, E., Weir, L.K., Wendel, P.J.,
785 Wheeler, L.B., & Young, A.M. (2018). Anatomy of STEM teaching in North American universities.
786 *Science* 359:1468-1470. doi: 10.1126/science.aap8892.

787 Sulik, J., Bahrami, B., & Deroy, O. (2021). The diversity gap: when diversity matters for knowledge.
788 *Perspectives on Psychological Science*.

789 Tannenbaum, S.C., & Berrett, R.D. (2005). Relevance of service-learning in college courses. *Academic
790 Exchange Quarterly* 9:197–201.

791 Ullevig, S.L., Vasquez, L.L., Ratclie, L.G., Oswalt, S.B., Lee, N., & Lobitz, C.A. (2020). Establishing a campus
792 garden and food pantry to address food insecurity: Lessons learned. *Journal of American College
793 Health* 9:1–5.

794 Vogelgesang, L.J., Astin, A.W. (2000). Comparing the effects of community service and service-
795 learning. *Michigan Journal of Community Service Learning* 7:25-34.

796 Wortman, S.E., Lovell, S.T. (2013). Environmental challenges threatening the growth of urban agriculture
797 in the United States. *Journal of Environmental Quality* 42:1283-1294.

798 Yan, D., Liu, L., Liu, X. & Zhang, M. (2022). Global trends in urban agriculture research: A pathway toward
799 urban resilience and sustainability. *Land* 11:117.

800 Yep, A., Nation, J.M., Moreno, R., Reyes, H., Torres, A., & De Smet, C. (2021). Nuestra Ciencia:
801 Transforming microbiology for Spanish-speaking elementary and college students. *Integrative and
802 Comparative Biology* 61: 1066–1077

803 Zizka, L., McGunagle, D.M., & Clark, P.J. (2021). Sustainability in science, technology, engineering and
804 mathematics (STEM) programs: Authentic engagement through a community-based approach.
805 *Journal of Cleaner Production* 279:123715.

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809 Figure legends.

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811 Figure 1. Conceptual framework linking urban agriculture to biology curriculum grounded by the AAAS
812 Vision and Change report (AAAS 2011).

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814 Figure 2. The Stewardship Garden at the University of St. Thomas (MN) illustrates how campus gardens
815 can be used in biology teaching and research (photo: B. Brown).

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817 Figure 3. Ray Warthen of Infinite Zion Farms in a vacant lot farm in Orlando, FL. (photo: E. Chapman)

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826 **Table 1.** Summary information from course descriptions in Biology-related departments in top-ranked
 827 research HEIs (n=20) and liberal arts HEIs (n=20). Data are mean + SE number of courses for which select
 828 terms are mentioned in course titles or descriptions. More detailed information in Table S1A-B.
 829

Institution type	Search term(s)				
“field” (related to field experiences for students)	“communit” OR “service” OR “experientia” (related to community-engaged learning)	“food” OR “agricultur” OR “agro” (related to food systems)	“urban” (related to urban systems)	“urban agriculture”	
Research HEIs	10.5 ± 2.34 (range: 0-34)	0.45 ± 0.17 (range: 0-3)	2.55 ± 0.72 (range: 0-11)	0.15 ± 0.11 (range: 0-2)	0.05 ± 0.05 (range: 0-1)
Liberal arts HEIs	5.20 ± 0.66 (range: 0-11)	0.20 ± 0.09 (range: 0-1)	1.55 ± 0.43 (range: 0-7)	0.35 ± 0.11 (range: 0-1)	0

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832 **Table 2.** Information from American Association for Sustainability in Higher Education (AASHE)
 833 Sustainability Tracking and Assessment System (STARS) reports and website scans about the topic of
 834 courses that use campus farms/gardens in teaching.
 835

Institution type	Course subject					
	Biology	Environmental Studies/Sustainability	Horticulture	Nutrition	Other	Total
Associate	1	0	2	0	0	3
Baccalaureate	12	16	1	0	4	33
Master	4	17	3	0	1	25
Doctoral/Research	7	16	3	3	4	33
Total	24 (26%)	49 (52%)	9 (10%)	3 (3%)	9 (10%)	94

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838 **Table S1A.** Institution-specific information from course descriptions in Biology-related departments in 20 top-ranked research HEIs. Data
 839 represent the number of courses for which select terms are mentioned in course titles or descriptions. “Field” mentions were filtered to include
 840 only courses that referenced field trips or field-based courses. “Communit” OR “service” OR “experientia” mentions were filtered to include only
 841 courses with community-engaged learning opportunities. “Food” OR “agricultur” OR “agro” mentions were filtered to include only courses
 842 related to food systems. “Urban” mentions were filtered to include only courses that focused on urban environments.

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Institution	Department	Search term(s)				
		“field”	“communit” OR “service” OR “experientia”	“food” OR “agricultur” OR “agro”	“urban”	“urban agriculture”
Brown University	Biology	9	0	4	0	0
California Institute of Technology	Biology	1	0	1	0	0
Columbia University	Biological Sciences	8	1	3	0	0
Cornell University	Animal Physiology; Biochemistry; Computational Biology; Ecology and Evolutionary Biology; General Biology; Genetics, Genomics and Development; Human Nutrition; Insect Biology; Marine Biology; Microbiology; Molecular and Cell Biology; Neurobiology and Behavior; Plant Biology; Systematics and Biotic Diversity	34	1	10	2	1
Emory University	Biology	8	0	1	0	0
Georgia Institute of	Biological Sciences	1	1	0	0	0

Technology

Johns Hopkins University	Biology	1	0	0	0	0
Massachusetts Institute of Technology	Biology	0	0	0	0	0
Michigan State University	Zoology, Biochemistry and Molecular Biology, Plant Biology	8	0	0	0	0
Northwestern University	Biological Sciences	1	0	0	0	0
Princeton University	Ecology & Evolutionary Biology, Molecular Biology	7	0	2	0	0
Purdue University	Biological Sciences	3	1	3	0	0
Stanford University	Biology	14	1	1	0	0
Texas A & M University	Biology, Microbiology, Zoology	1	0	0	0	0
University of California – Berkeley	Integrative Biology, Molecular and Cell Biology, Plant and Microbial Biology	24	0	11	0	0
University of California - Los Angeles	Ecology and Evolutionary Biology; Bioinformatics; Molecular, Cell, and Developmental Biology; Microbiology, Immunology, and Molecular Genetics	34	3	2	0	0
University of Michigan	Ecology and Evolutionary Biology; Molecular, Cellular, and Developmental Biology	14	1	7	1	0

University of Virginia	Biology	12	0		2	0	0
University of Washington	Biology	21	0		2	0	0
Yale University	Biology; Ecology and Evolutionary Biology; Molecular, Cellular, and Developmental Biology	9	0		2	0	0
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848 **Table S1B.** Institution-specific information from course descriptions in Biology-related departments in 20 top-ranked liberal arts HEIs. Data
 849 represent the number of courses for which select terms are mentioned in course titles or descriptions. “Field” mentions were filtered depending
 850 on whether it referenced to field trips or courses. “Communit” OR “service” OR “experientia” mentions were filtered depending on whether they
 851 referred to community-engaged learning opportunities. “Food” OR “agricultur” OR “agro” mentions were filtered depending on whether they
 852 were related to food systems. “Urban” mentions were filtered depending on whether they referred to urban environments
 853

Institution	Department	Search term(s)				
		“field” (related to field experiences for students)	“communit” OR “service” OR “experientia” (related to community- engaged learning)	“food” OR “agricultur” OR “agro” (related to food systems)	“urban” (related to urban systems)	“urban agriculture”
Amherst College	Biology	3	0	1	0	0
Barnard College	Biology	1	0	0	0	0
Bowdoin College	Biology	4	0	1	0	0
Carleton College	Biology	2	1	2	0	0
Claremont McKenna College	Biology	9	0	0	0	0
Colby College	Biology	7	0	3	0	0
Colgate University	Biology	7	0	0	0	0
Davidson College	Biology	9	0	0	1	0

Grinnell College	Biology	7	0		0	0	0
Hamilton College	Biology	3	0		4	1	0
Haverford College	Biology	0	0		1	0	0
Middlebury College	Biology	11	1		1	0	0
Pomona College	Biology	8	0		0	0	0
Smith College	Biological Sciences	8	0		1	1	0
Swarthmore College	Biology	5	1		1	0	0
University of Richmond	Biology	2	0		0	1	0
Washington and Lee University	Biology	4	1		2	0	0
Wellesley College	Biological Sciences	4	0		5	1	0
Wesleyan University	Biology	5	0		7	1	0
Williams College	Biology	5	0		2	1	0

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Table S2. Questions from American Association for Sustainability in Higher Education (AASHE) Sustainability Tracking and Assessment System (STARS) reports that were analyzed for integration of campus farms/gardens in teaching or research.

Section of report	Question
EN-3: Student Life	Does the institution have gardens, farms, community supported agriculture (CSA) or fishery programs, and/or urban agriculture projects where students are able to gain experience in organic agriculture and sustainable food systems?
EN-3: Student Life	A brief description of the gardens, farms, community support agriculture (CSA) or fishery programs, and/or urban agriculture projects
EN-3: Student Life	The website URL where information about the gardens, farms or agriculture projects is available
AC-8: Campus as a Living Laboratory	Is the institution utilizing its campus as a living laboratory for multidisciplinary student learning and applied research in relation to Food & Dining?
AC-8: Campus as a Living Laboratory	A brief description of the student/faculty projects and how they contribute to understanding campus sustainability challenges or advancing sustainability on campus in relation to Food & Dining
AC-8: Campus as a Living Laboratory	Is the institution utilizing its campus as a living laboratory for multidisciplinary student learning and applied research in relation to Grounds?
AC-8: Campus as a Living Laboratory	A brief description of the student/faculty projects and how they contribute to understanding campus sustainability challenges or advancing sustainability on campus in relation to Grounds

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