12-2021

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Landscape and Urban Planning 216 (2021) 104259

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Landscapes as living laboratories for sustainable campus planning and stewardship: A scoping review of approaches and practices

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HIGHLIGHTS

- Living laboratories employ applied and transdisciplinary research, experiential learning, and co-creation of the campus.
- Campus landscapes can serve as living laboratories for project-based learning and environmental stewardship.
- Landscapes as living laboratories provide opportunities to consider, implement.
- Landscapes as living laboratories could more strongly connect to campus sustainability plans and policies.

ARTICLE INFO

Keywords:
Living laboratory
Learning landscapes
Campus sustainability
Higher education
Adaptive co-management

ABSTRACT

Living laboratories are increasingly employed to support campus sustainability and student learning. This research explored how living labs are defined in relation to the biophysical landscape, how they are integrated into teaching and learning, how students are engaged, and how they connect to university sustainability goals. Previous reviews focus on living laboratories or learning landscapes, but no prior review has explored the application of these concepts specifically to the biophysical landscape of university campuses. We employed a scoping review which resulted in 28 articles for analysis. Projects most consistently employed the terms "learning landscapes," "sustainable campus landscape," and "adaptive co-management" as articulations of living laboratories that integrate campus physical landscapes. Students have been engaged in design, planning, installation, stewardship, monitoring, and management of campus landscapes through courses, research, and co-curricular activities. The majority of projects engaged with landscapes as living laboratories through environmental science, design, and other allied disciplines. Other disciplines could also engage with landscapes as living laboratories to promote sustainability. Projects also could more explicitly connect faculty and student engagement with broader campus sustainability goals and plans. More consistent application of terms may help other universities to determine the best actions for their campus when incorporating landscapes into living laboratories.

1. Introduction

Campus sustainability is of growing importance, not only as a means to minimize environmental harms but also as a way to promote concepts of ecological health, human well-being, and sustainable systems. Universities across the world have promoted integration of sustainability through policies, research, curricula, and infrastructure (Filho et al., 2020). The physical campus landscape often reflects the identity and values of the university, and campuses that promote sustainability frequently manifest these values in the built environment (Zhang, Zhou, Schmidt, & Garland, 2016). However, how universities are integrating sustainable features of the campus biophysical landscape into teaching and student engagement is less clearly articulated in the research literature. Our understanding is limited by a lack of consistent frameworks, terms, and best practices to describe the campus landscape as an interconnected ecological system for teaching and learning.

"Living laboratory" is an increasingly popular term to encompass a range of strategies that engage students, faculty, staff, and/or community in campus sustainability activities (Evans, Jones, Karvonen, Millard, & Wendler, 2015; Filho et al., 2020). In 2013, the Association for the Advancement of Sustainability in Higher Education (AASHE), together with the Arbor Day Foundation, created the How-To Guide for Promoting Sustainable Campus Landscapes. The guide includes benefits of sustainable campus landscapes, means to increase community

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https://doi.org/10.1016/j.landurbplan.2021.104259
Received 29 May 2021; Received in revised form 9 August 2021; Accepted 22 September 2021
Available online 30 September 2021

engagement, and ways to promote and track these systems once employed. This guide defines the term "living laboratory" as a site of research on sustainable landscapes and ecosystem services. They assert that "because campus landscapes are so visible and accessible, landscape initiatives are a great way to build awareness and promote learning among the entire campus community as well as the surrounding community" (p.1). Similarly, Filho et al. (2020) promote living labs as a means to achieve the United Nations Sustainable Development Goals, through their potential focus on waste, water, energy, ecosystem protection, and social responsibility. Some have suggested that these direct linkages between biophysical landscapes and learning are still underrepresented in higher education sustainability plans and processes (Krasny & Delia, 2015; Wals, 2014). Living laboratories are promoted as a means to support campus sustainability, mental restoration, and student engagement and learning. But when we sought to understand specific ways that the campus biophysical landscape was employed in a living laboratory framework, we found that conceptions were inconsistent, vague, and hard to disentangle from the much broader framework. We know that excellent models exist for how landscapes can be integrated within living laboratory frameworks. For example, the University of Minnesota (2021) engages its campus landscapes into "spaces for innovation, testing, demonstration, and learning" (para 1); the University of California, Davis Learning by Leading program provides students with opportunities to lead environmental sustainability, restoration, and education experiences "by working in teams to solve real-world problems" in conjunction with the UC Davis Arboretum and Public Garden (UC Davis, 2021, para 1); and the California State University system of 23 campuses promotes a Campus as a Living Lab program to integrate sustainability into academics through projects that range from ecological restoration to food systems, energy, and waste transformations (CSU, n.d.). However, when we initiated our own research to inform landscape planning efforts on our campus, we found it challenging to identify scholarly literature about these programs and projects due to inconsistencies in terminology and framework references. This article therefore sets out to clarify terms and to identify ways that the campus biophysical landscape itself is being used to bring landscapes and learning together in higher education settings.

2. Background

2.1. Campus landscape sustainability

The benefits of campus sustainability are well documented (Wals & Blewitt, 2010). Natural landscapes can foster biodiversity conservation and ecosystem services (Colding & Barthel, 2017; Way, Matthews, Rottle, & Toland, 2012). Specific ecological benefits of sustainable landscapes can include increased wildlife habitat, native species conservation, sustainably managed stormwater runoff and rainwater harvesting, increased water quality, pest management and landscape stewardship (Bruce, 2011; Colding & Barthel, 2017; Krasny & Delia, 2015; Rieske et al., 2019; Tao, Newman, Arnold, Li, & Kim, 2019; Way et al., 2012). Campus landscapes can also be sites for sustainable energy production, green infrastructure, and remediation of toxic sites (Colding & Barthel, 2017; Tao et al., 2019; Way et al., 2012). Consideration of campus landscapes also can be linked to historic preservation and campus heritage planning (Bruce, 2011; Martin, 2011; Smith & Spencer, 2012). Campus community gardens, primarily for fruit and vegetable production, are a common but potentially less well-integrated aspect of campus landscape sustainability, due to their ad hoc management (Marsh et al., 2020). Increasingly, campus landscapes are discussed for the human health and restorative benefits nature can provide. Students are reporting increased levels of stress, and the campus landscape is viewed as a space that can be restorative to student health and well-being (Foellmer, Kistemann, & Anthonj, 2021; Lu & Fu, 2019; Hipp, Gulwadi, Alves, & Sequeira, 2016; Krasny & Delia, 2015; McFarland, Waliczek, & Zacicek, 2008; Speake, Edmondson, & Nawaz, 2013).

2.2. Landscapes as sites for learning

The Alnarp Landscape Laboratory explicitly bridges connections between the built environment and nature. This landscape laboratory has integrated concepts of experiential learning, local knowledge, grappling with complexity, and viewing the landscape in contextual and holistic ways for more than 30 years (Gustavsson, Gunnarsson, & Wiström, 2019). The Alnarp Landscape Laboratory also engages in co-management of urban woodlands with students, faculty, and children (Fors, Jansson, & Nielsen, 2018). Emphasis of these living laboratories is on making places work for people as an essential aspect of sustainability.

These concepts have moved into the university campus more recently. A review of articles published in the *International Journal of Sustainability in Higher Education* found that from 2001 to 2010, most articles were focused on infrastructure (environmental management, university greening) and systems (reducing the university's ecological footprint) (Wals & Blewitt, 2010). Wals and Blewitt's (2010) review found that consideration of pedagogy, learning, instruction, and community outreach as a focus of sustainability in higher education began to appear more frequently closer to the end of their review period (2010).

Student engagement can benefit the planning, creation, and maintenance of sustainable landscapes. Krasny and Delia (2015) suggested that campus natural areas are under-utilized in higher education sustainability initiatives. They suggested that despite growing evidence of the positive human benefits that can be realized through direct connection of students and nature, university approaches to sustainability often spend more time focused on initiatives that reduce greenhouse gas emissions or consumption and less on fostering student engagement in stewardship of the natural spaces of campus landscapes. Their research suggests that stewardship not only directly benefits the campus physical environment but also contributes to a stronger sense of place among students and can play an important role in supporting students' mental well-being (see also Foellmer et al, 2021; Seitz, Reese, Strack, Frantz, & West, 2014) Other studies on the benefits of campus landscapes suggest that greenspaces on campus can promote a sense of belonging (Foellmer et al., 2021), foster attention restoration (Felsten, 2009; Lu & Fu, 2019), increase academic performance, and improve quality of life (McFarland et al., 2008). Sense of belonging among students is particularly important for student retention, particularly for students who experience mental health issues or disabilities and for students from underrepresented groups, such as low income, minoritized, or first-generation college students (Davis, 2012; O'Keeffe, 2013).

Londero Brandli and colleagues (2020) suggested that green areas on university campuses can be used to promote student learning, aligning with United Nations Sustainable Development Goal 4 for education, as well as Sustainable Development Goal 15 for biodiversity protection. However, in an evaluation of a Brazilian campus, they found that the university engaged students and community but could do more to enhance ecological practices. They promoted a co-management approach similar to that of Krasny and Delia (2015), above, to achieve this.

3. Method for scoping review

Zhang et al. (2016) articulated one of the central benefits of interweaving the campus landscape and learning: opportunities for experiential learning are literally outside the door of the traditional classroom. This accessibility is important for in-depth integration into learning across the university curriculum. And yet our understanding of this approach to sustainability education is hampered in part by the broad range of terms that are inconsistently employed or overlapping in meaning. As an example, a recent research review of "higher education sustainable development" promotes the use of the term "learning landscape," and yet the authors' use of this term does not appear to uniformly (or even conceptually) apply to the actual physical landscape of the campus (Backman, Pitt, Marsden, Mehmood, & Mathijs, 2019).

Additionally, living laboratories are employed in technology and design innovation, and some of these authors employ the term "landscape" not as a land area, but as a terrain for intellectual activity. For example, Pallot, Trousse, Senach, and Scapin (2010) apply the term to an open-access archive for information dissemination. While these authors use "learning landscape" as a term that includes virtual landscapes and other learning "spaces" that are not actually part of the biophysical landscape, our use of the term applies to landscape spaces that are socio-ecological and can include gardens, wetlands, bioswales, open space, green infrastructure or other aspects of the physical landscape, depending on the university context. "Landscape" as a term is essential to planning and design of the biophysical campus, but identifying model work in the literature is made challenging by these alternative uses. We therefore sought to undertake a literature review to understand how living laboratories in the physical landscape are defined, described, and used to support student learning and engagement on college campuses. We employed a scoping review (Munn et al., 2018) with the goals of clarifying key concepts and definitions in the literature and examining how living laboratories are employed in university contexts. We began with four questions to guide our research about campus landscapes as living labs:

- How are living labs defined when applied in contexts that utilize the biophysical landscape?
- How is the biophysical landscape integrated into living labs for teaching and learning?
- How are students engaged in the process of designing and learning about the biophysical landscape within living labs?
- How do biophysical landscapes as part of living labs fit into a campus's broader sustainability goals?

To begin, we conducted an initial literature review to identify keyword search terms that were associated with articles related to campus landscapes and the concept of a living laboratory. Through an initial assessment of "living laborator*" and "learning landscape*" we arrived at seven search terms for our review: "education for sustainable development," "learning laborator*," "learning landscape*," "living laborator*," "green campus," "sustainable campus," "sustainable landscape". After identifying search terms, we conducted an academic database search using ProQuest Agriculture and Environmental Science, Ebsco, Ebsco Greenfile, ScienceDirect, Wiley, SpringerLink, Academic Science Premier, and JSTOR using each of these search terms individually. We did not use Google Scholar because it is a repository of articles from other databases and sources that does not allow for precise search terms. Our search used filters for scholarly articles and trade journals but excluded book reviews, conference announcements, competitions or design awards, and funding announcements. We also eliminated duplicates that appeared in more than one database search. We did not use filters for dates of publication. The literature search was conducted between July and September 2020.

Because our research was specifically interested in identifying ways that the biophysical landscape is utilized in living laboratory contexts, we identified the following post-search exclusion criteria:

- Projects that do not pertain to the physical landscape of the campus
- Projects focused on indoor environments or building performance
- Projects focused on sustainable systems (e.g., transportation, energy, solid waste, climate change modeling) without integration into the physical landscape
- Projects that were not situated within higher education learning environments (K-12 school projects, city-wide learning landscapes, study abroad, and off-campus landscape restoration were therefore excluded)
- Evaluation or sustainability reporting tools
- University policies to support sustainability initiatives not directly tied to the biophysical environment
- Software and modeling programs (including the visualization modeling program STELLA, the Systems Thinking, Experiential Learning Laboratory with Animation), which includes one of our search terms in its program name but does not pertain to the biophysical environment.

Based on these search and screening criteria, the search resulted in 119 articles. From the 119 articles, we then reviewed each article based on our four guiding research questions and entered brief summaries for each topic into a spreadsheet. Projects that addressed none of these topics, based on full article review, were eliminated from additional review. The first author initially analyzed each article; the second author reviewed this work and where discrepancies were identified in scoring or analysis, these articles were discussed and revised based on mutual agreement. This resulted in a total of 28 articles that met the search and screening criteria as well as questions. The 28 articles were then coded in NVivo qualitative research software program for definitions or language that helped to frame the concept of a living laboratory.

4. Results

4.1. Landscape as part of living labs: a growing concept

Of the 28 articles we reviewed, 6 (21%) were published prior to 2010 (years 2000–2008), and 22 (79%) were published in the last ten years (Table 1). More than a third (36%) of review papers were published in the last three years of review (2018–2020) (Table 1). This demonstrates the slow but steady emergence of landscapes as part of campus living laboratories for student engagement and teaching. Beginning in 2008, the articles also showed more consistent and deliberate connections between landscape significance in terms of sustainability principles as well as for teaching and learning.

4.2. Definitions and framings of campus landscapes as living laboratories

The articles identified in our scoping review revealed multiple terms being applied to the same overarching concept (Table 2), even after our exclusionary criteria were applied. The term living laboratory integrates university campus in a research approach, encompassing student engagement, campus transformation, and principles of sustainability. When describing projects that employ the biophysical landscape as a pedagogical tool on campus, authors most consistently used the terms "learning landscapes," "sustainable campus landscape," and "adaptive co-management," all of which describe aspects of a living laboratory framework (Fig. 1; Table 2). Experiential learning was also a frequent term to describe campus-based projects and co-curricular activities and is a key concept of the living laboratory framework.

Many projects that employed the frame of a living laboratory engaged multiple academic disciplines and campus stakeholders in generating new thinking for how to develop a sustainable campus. According to Erixon Aalto and colleagues (2018), inter- and transdisciplinary approaches involve the crossing of subject boundaries in order to create new knowledge and integrative theory, greater than what can be achieved through isolated disciplines. When most effectively employed, students, faculty, and administration all work together to transform the campus, often while engaging the broader community, thus reaping the benefits of the living laboratory framework.

We found the living laboratory framework to be the broadest concept of the four we identified in our review (Fig. 1). Our review suggests that a living laboratory is an approach that "integrates research and innovation processes through the co-creation, exploration, experimentation and evaluation of innovative ideas" (Colding & Barthel, 2017, p.9), wherein students can apply new concepts they are learning directly to the campus landscape (Shriberg & Harris, 2012), and wherein these practices are situated within a "given territorial context" of the socio-cultural and biophysical campus landscape (Zen, 2016, p.940) (Fig. 1;

Table 1
Review articles as related to research questions.

Date Range	Number of Articles (%) (N = 28)	Article from Review	Research Questions and Articles that Address Them			
			Living lab and allied frameworks defined or discussed	Biophysical landscape integrated	Student engagement in designing or learning with biophysical landscape	Linkages to broader sustainability goals
2000–2003	4 (14.2%)	Tittley (2000)	X	X	X	X
		Barlett (2002)		X		
		Calkins (2002)	X	X	X	X
		Franklin et al. (2003)	X	X	X	X
2004–2006	1 (3.6%)	Parker (2006)		X	X	
2007–2009*	1 (3.6%)	Savanick et al. (2008)	X	X	X	X
2012*-2014	6 (21.4%)	Cheang et al. (2017)	X	X	X	X
		Hansen (2012)	X	X	X	X
		Shriberg & Harris (2012)	X	X	X	X
		Smith (2012)	X	X	X	X
		Speake et al. (2013)		X		
		Krasny & Delia (2014)	X	X	X	X
2015–2017	6 (21.4%)	Hipp et al. (2016)		X		
		Zhang et al. (2016)	X	X	X	X
		Cheang et al. (2017)		X	X	
		Colding & Barthel (2017)	X	X	X	X
		Roman et al. (2017)		X		X
		Zen (2016)	X	X	X	X
2018–2020	10 (35.7%)	Erixon Aalto et al. (2018)	X	X	X	X
		Oyama et al. (2018)	X	X	X	X
		Bergquist et al. (2019)	X	X	X	X
		Genta et al. (2019)		X		X
		Li et al. (2019)	X	X		X
		Rieske et al. (2019)	X	X	X	X
		Robbins et al. (2019)	X	X	X	
		Tao et al. (2019)	X	X	X	X
		Kurteslan (2020)	X	X		X
		Misni et al. (2020)		X		X

* No articles in our review were published in the years 2009–2011.

Table 2). Learning landscapes and sustainable campus landscape are means to apply these living laboratory principles in the biophysical campus landscape (Fig. 1). Adaptive co-management most often is a process for creating strong and inclusive policy, setting up the foundation for co-curricular activities and institutionalization of sustainable practices, and ultimately leading to sustainable campus transformation and the engagement of students outside of curriculum (Fig. 1). These more specific terms describe the varying approaches of living laboratories (Fig. 1) and elaborate ways a living laboratory can be developed.

Learning landscapes typically employ hands-on learning through intentional use of greenspaces and are commonly employed within universities through the sciences or environmental design disciplines. Learning landscapes provide opportunities to directly incorporate students in the design and planning process, providing insight on what the campus community may need, and furthering student knowledge of sustainability in practice (Table 2; Fig. 1).

The "sustainable campus landscape" term appears to be used most frequently to denote the biophysical landscape (Franklin, Durkin, & Schuh, 2003; Misni et al., 2020; Kurtaslan, 2020) and is a place where living laboratory practices can be applied broadly but does not reflect a specific mode of engagement with the landscape (Table 2; Fig. 1). Sustainable campus landscapes create the opportunity for experiential learning and embody campus values, including campus sustainability goals (Zhang et al., 2016). Sustainable campus landscapes provide a diversity of services, including ecological services and student engagement through recreation, health and well-being, and sustainability awareness. Students can be involved through co-management, course integration, or research (Krasny & Delia, 2014) but are not always engaged in sustainable campus landscape design, planning, or stewardship.

"Adaptive co-management" was linked with the living laboratory framework as a way to encompass learning-by-doing, integrate multiple knowledge systems, emphasize flexibility of management structures, and advance collaboration through power sharing at multiple scales (Table 2; Fig. 1) (Krasny & Delia, 2014; Tao et al., 2019). Co-management is often accomplished through co-curricular activities

Table 2
Terms and representative definitions from scoping review.

Term	Articles that define the term	Representative Definitions
Living Laboratory	Colding & Barthel (2017) Oyama et al. (2018) Rieske et al. (2019) Shriberg & Harris (2012) Tao et al. (2019) Zen (2016)	"A research approach that integrates research and innovation processes through the co-creation, exploration, experimentation and evaluation of innovative ideas" (Colding & Barthel, 2017, p.9) "The campus is the most readily available laboratory for hands-on projects, and acts as a shadow curriculum for students to apply to the campus what they learn in the classroom" (Shriberg & Harris, 2012, p.155) "The co-creation process in integrating research and innovation in a systematic way, on a given territorial context" (Zen, 2016, p.940).
Living Learning Laboratory	Shriberg & Harris (2012)	"Strategies and pedagogies in project-, problem-, and place-based learning." (Shriberg & Harris, 2012, p.155)
Learning Landscape	Robbins et al. (2019)	A place "where community teachers, students, and families gathered to develop and deliver both cultural and academic curriculum" (Robbins et al., 2019, p.113)
Sustainable Campus Landscape	Krasny & Delia (2014) Zhang et al. (2016)	Embodies campus values, provides, spaces for study and recreation, ecosystem services and human well-being, and builds awareness for sustainability (Krasny & Delia, 2014) "Sustainable campus landscapes embody university values and function as living laboratories" (Zhang et al., 2016, p.47)
Adaptive Co-management	Erixon Aalto et al. (2018) Krasny & Delia (2014)	"Encompasses 'learning-by-doing, integrating multiple knowledge systems, emphasizing flexibility of management structures, and advancing collaboration through power sharing at multiple scales'" (Krasny & Delia, 2014, p.3)
Experiential Learning	Hansen (2012)	Learning as knowledge creation through concrete experience, reflective observation, and active experimentation in a cyclical manner (Hansen, 2012)

rather than formal learning. Students who participate in adaptive co-management apply knowledge in a variety of settings, whether through formal discussions with administration advocating for learning landscapes, organizing stewardship efforts with other campus groups and outside entities, or participating in forums to inform campus policy. These activities allow students to apply knowledge acquired from formal curricula or through the experiential learning process of co-management itself, through co-curricular contexts, such as clubs or volunteering, that take place outside the formal classroom.

4.3. Integration of campus landscapes into teaching

Campus landscapes provide opportunities for students and faculty to engage in place-based learning projects that garner environmental stewardship and promote sustainable thinking (Bergquist, Hempel, & Green, 2019; Shriberg & Harris, 2012; Smith, 2012; Rieske et al., 2019). Our review reflects an increase in the incorporation of landscape as a pedagogical tool for teaching and learning within the past eight years. Of the 28 articles, 14 (50%) used this framework through explicit integration into courses and curricula (Calkins, 2002; Chambless, Parvaz, Chesson, & Ruff, 2012; Hansen, 2012; Oyama, Pasquier, & Mojica, 2018; Robbins, Robbins, & Frailey, 2019; Savanick, Strong, & Manning, 2008; Shriberg & Harris, 2012; Smith, 2012; Tao et al., 2019; Zen, 2016; Zhang et al., 2016) (Table 1).

Degree programs in environmental design reflect a niche area that require both traditional class settings as well as hands on learning experiences to gain requisite knowledge for the field. For example, landscape design students at the University of Florida participated in planning and designing a learning landscape for the campus' Food and Agricultural Sciences Center through design, planning, and installation of demonstration gardens (Hansen, 2012). According to Hansen (2012), "public demonstration gardens are one of the primary means by which adults learn about environmental concepts and transform their perspective of the environment" (p.31).

Tennessee State University found learning landscapes to be a low investment project that can start small and build to enrich their newly proposed environmental science degree, with concentrations in environmental design, biofuels, and green energy. The College of Agriculture, Human and Natural Sciences developed a plan for an area on campus to include rain gardens, bioswales, constructed wetlands, plantings for carbon sequestering, and water harvesting technology (Ou, Lin, Jing, & Lin, 2006; Smith, 2012). Tao et al. (2019) established an interdisciplinary course across university departments to consider green infrastructure design for stormwater management. The strength of such projects is often the transdisciplinary approach to learning that considers problems holistically, allowing students to engage with others in the consideration of policy, institutional structures, and sustainability systems.

Planning and maintenance of gardens are also integrated into a variety of courses. Students at the University of Utah created and manage two campus gardens, which have been used for teaching courses in Global Environmental Issues and Ecological Principles of Organic Gardening (Chambless et al., 2012). Students in these courses used the campus landscape to explore topics of climate change, pollution, population growth, biodiversity, poverty, and community. Cheang et al. (2017) explored the adaptation of an existing campus garden with designers, educators and students to understand how an eco-garden could be employed to promote education for sustainability. They engaged both environmental studies degree students as well as students from other disciplines. Service learning is also a mechanism to link landscapes and teaching. At the University of Nebraska Omaha, Indigenous gardens highlight Native American studies, culture-based opportunities for Native American youth, and Native horticultural practices (Robbins et al., 2019). Service learning in this context is a means to support both the development and maintenance of gardens that promote Native lifeways.

Zhang et al. (2016) directly identified sustainable campus landscape practices in China and the United States. The Environmental Institute of Houston directly integrates sustainable campus landscapes as part of a living laboratory, leading efforts to create native coastal wetlands on campus. These wetlands provide research opportunities in the areas of water quality, wetland biology, and class field trips (Zhang et al., 2016). The China Three Gorges University also uses sustainable campus landscapes as part of a living laboratory, involving students from art and design to make plans for undeveloped areas of campus while civil engineering students evaluate high and steep slope ecological restoration technology (Zhang et al., 2016). Bergquist et al. (2019) also described integration of sustainability principles, particularly for regenerative campus design, into workshops and teaching.

4.4. Integration of students into adaptive co-management and co-curricular activities

Living laboratories as an overarching framework also provide opportunities to apply and practice sustainability principles outside the formal curriculum. Our review revealed adaptive co-management as an approach to engaging students in collaborative activities that emphasize learning by doing, often through co-curricular activities that engage students outside the formal curriculum. Co-management strategies included student engagement in stewardship activities, green infrastructure, resilience planning, and policy. Of the 28 articles in our review 12 (43%), used this framework through explicit mention of student

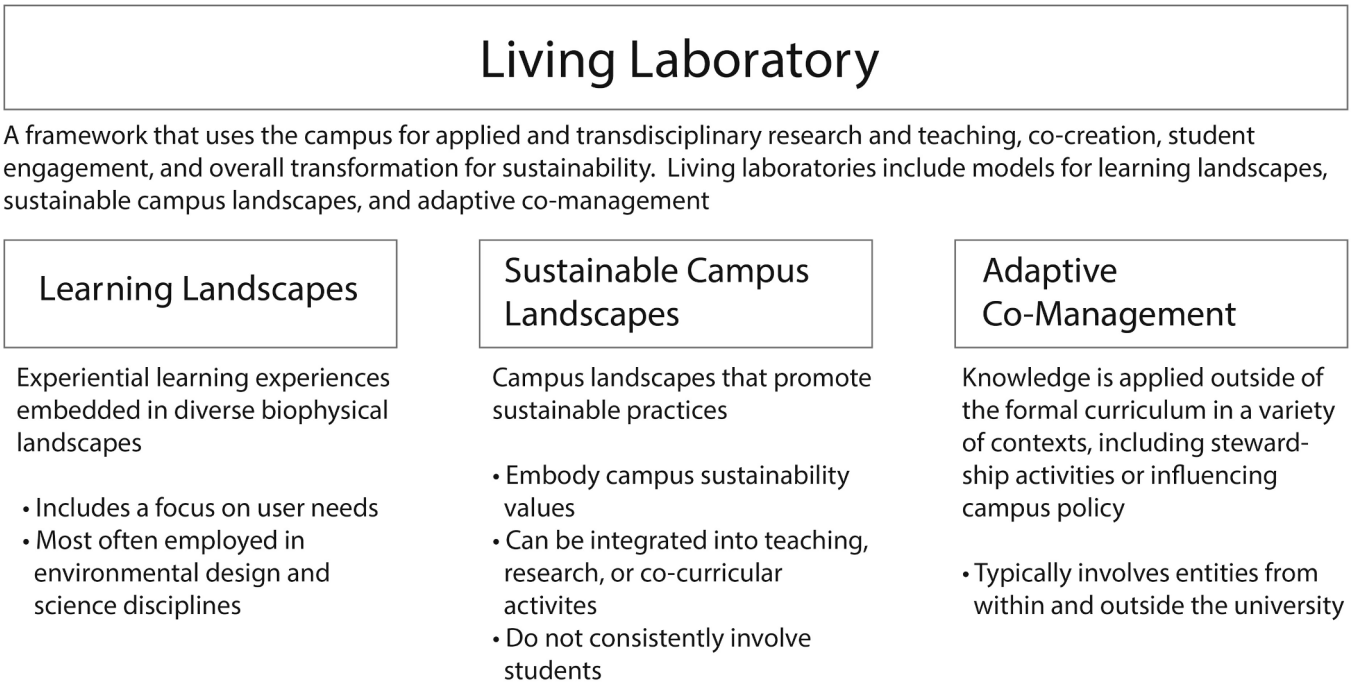

Fig. 1. Working definitions for consistent application of terms across living laboratory projects that utilize campus biophysical landscapes.

engagement in co-management strategies (Chambless et al., 2012; Cheang, So, Zhan, & Tsoi, 2017; Colding & Barthel, 2017; Erixon Aalto, Marcus, & Torsvall, 2018; Krasny & Delia, 2014; Rieske et al., 2019; Robbins et al., 2019; Savanick et al., 2008; Shriberg & Harris, 2012; Smith, 2012; Tao et al., 2019; Tittley, 2000). Student involvement in co-management often is focused on planting or maintenance (Krasny & Delia, 2014; Rieske et al., 2019; Robbins et al., 2019; Zhang et al., 2016), but also spanned into planning (Hansen, 2012; Robbins et al., 2019; Savanick et al., 2008; Shriberg & Harris, 2012; Zhang et al., 2016). Savanick and colleagues (2008) described how students at Carleton College worked with facilities management to research, plan, design, and raise money for green roof installation.

Aspects of co-management theory also demonstrate collaboration with outside entities, such as city governments, non-profits, or volunteer groups (Krasny & Delia, 2014; Zhang et al., 2016). The Environmental Institute of Houston's coastal wetland project, although integrated into curriculum, also has motivated students, faculty, staff, and members of the community to volunteer their time outside of class during workdays that occur on the wetland every six months (Zhang et al., 2016). The collaboration between the group of students, faculty, staff, and outside entities working together to manage the site is a defining principle of adaptive co-management theory.

Co-management also was described as "a central concept within resilience science" which can contribute to campus sustainability (Erixon Aalto et al., 2018). Erixon Aalto et al. (2018) described strategies for integrating socio-ecological processes that promote resilience through urban design in Stockholm, Sweden. They described adaptive co-management as a way to promote civic engagement and active management of greenspaces. Tao et al. (2019) employed a multi-phased, multi-year process to engage students in design planning for a living green architecture lab. Beginning with conceptual design research, students designed and installed a rain garden as a form of green infrastructure on the Texas A&M University campus. Once the rain garden was installed, students moved into a monitoring phase to assess how the garden affected water quality compared to before its installation. This project therefore moved from planning and design, to construction, through co-management processes, and allowed for significant experiential learning collaboration across campus institutions, aspects of adaptation that are part of the co-management process.

Cornell University exemplifies the benefits adaptive co-management can bring to a university campus in transforming policy. At Cornell, this approach was applied between administration and multiple student organizations. The student organization Friends of the Gorge (FOG) engages in stewardship events, trail maintenance, tree planting, and an off-campus Adopt a Gorge collaboration. Cornell's administration involved Friends of the Gorge in discussions about student perspectives on gorge safety that would inform campus policy (Krasny & Delia, 2014). The only other living laboratory in our review to explicitly link co-management approaches with campus policy was in China (Zhang et al., 2016). Faculty and students at the China Three Gorges University identified campus planning policies that promoted the development of local cultural and spiritual elements of the campus landscape, analyzed how groups used the campus environment, and made recommendations for improving the existing campus landscape based on research outcomes.

4.5. *Linking landscape projects to campus sustainability goals*

Some papers in our review referred to landscapes as embodiments of university values and culture (Krasny & Delia, 2014; Savanick et al., 2008; Zhang et al., 2016). Zhang et al. (2016) described the landscape as "the most highly visible representation of the university and its relationship to nature," expressing the soul, personality, and cultural symbolism of the campus, as well as its commitments to sustainability (p.48). In our review, 14 papers (50%) explicitly mentioned campus sustainability goals or embodying campus sustainability values (Barlett, 2002; Franklin et al., 2003; Genta, Favaro, Sonetti, Barioglio, & Lombardi, 2019; Hansen, 2012; Hipp et al., 2016; Krasny & Delia, 2014; Kurtaslan, 2020; Misni et al., 2020; Rieske et al., 2019; Roman et al., 2017; Tao et al., 2019; Tittley, 2000; Zen, 2016; Zhang et al., 2016). Some review papers referred to campus sustainability efforts broadly (Table 1), within a global or academic context, but did not give details about how projects or research linked directly to a specific institution's sustainability plans or goals.

In 2008, Savanick and colleagues suggested that campuses had not taken advantage of sustainability projects as an academic resource. This

sentiment has later been echoed by others (Krasny & Delia, 2014; Zhang et al., 2016). In their analysis of two universities in China and the U.S., Zhang et al. (2016) found that while both universities have become more sustainable in recent years, the universities have not fully embraced the potential of sustainable campus landscapes. Zhang and colleagues advocated for "a redefinition of the landscape as a collective, interactive, and ongoing process of natural and human innovation" (p.41) and suggested that landscape can become a central vehicle for advancing university sustainability. Savanick and colleagues (2008) also emphasized that while many campuses implement sustainability projects, the administrative and operational sectors of the campus work in isolation from learning and research experiences of academic units. They called for stronger bridging between faculty and student activities and administration, operations, and lead decision makers.

Chambless et al. (2012) discussed the significance of linking living laboratory practices to institutional structures when they described how a 4,000 acre campus garden "was in peril" as a core faculty member's retirement approached, because the gardens were not part of the university's campus master plan. A desire to maintain the benefits of this space for teaching and learning motivated a coalition of faculty, students, and staff to campaign for more administrative support, "thus demonstrating the garden's intrinsic value to the campus as a whole" (p.160).

Zhang et al. (2016) emphasized that while, for example, projects that test water quality on campus teach about sustainability and use the campus as a living laboratory, they do not connect more broadly to transformation of campus sustainability goals. Three papers in our review explicitly linked campus sustainability practices of faculty and students to university policies and sustainability goals (Krasny & Delia, 2014; Rieske et al. 2019; Tao et al., 2019). The University of Kentucky linked student involvement in maintaining and expanding the tree canopy to the administration's priority for maintaining the "beauty and ecosystem function of green infrastructures" when developing campus facilities (Rieske et al., 2019). As a reflection of these values, an outside organization, administration, and a service fraternity participated in a "Scale Scrub" event after a honey locust infestation of the tree canopy. Student volunteers helped with the remediation of the campus trees, learning about the honey locust, their effects on the tree species, and specific pest management strategies (Rieske et al., 2019). Although not directly termed, the University of Kentucky executed adaptive co-management strategies to create a living laboratory on campus, in turn helping achieve one of the campus' goals to preserve the tree canopy.

Krasny and Delia (2014) described the relatively recent insertion of natural areas and open space management into the Sustainability Tracking, Assessment & Rating System (STARS) that is generated by the Association for the Advancement of Sustainability in Higher Education. STARS 2.0 included criteria for sustainable landscape management. The rating system also links categories to curriculum through student monitoring and involvement in campus landscape systems. Krasny and Delia (2014) linked these criteria through the framing of adaptive co-management, as described in the previous section. They described ways that policies and practice intersect, particularly around the issue of student safety at campus creeks that form deep gorges. Linkages between policy and practice in this case were most apparent through Krasny's role as a faculty member who engages both with campus policies and as the faculty lead of a student organization (Friends of the Gorge) involved with restoration.

In many cases, it is possible that faculty on other campuses similarly play bridging roles between campus policies and institutionalized practices and the implementation of living laboratory projects, but these roles, and linkages between campus policies and practice, were not clearly articulated in our review articles. For example, students at the University of Florida were introduced to existing site constraints and requirements by planning staff for a project to design demonstration gardens for their campus landscape, and their design concepts and plans later were critiqued by planning staff based on institutional constraints and interests (Hansen, 2012). In this way, students learned about the applications of campus policies to the planning process. The article by Hansen, however, does not articulate directly the relationship between the demonstration garden and campus sustainability goals. In cases such as in Hansen's article, it is possible that faculty or others on campus played a bridging role between campus policies and institutionalized practices and the implementation of living laboratory projects, but these roles, and linkages between campus policies and practice, were not clearly articulated in our review articles. Bergquist, Hempel, and Green (2019) also described a comprehensive design process at the Swedish University of Agricultural Sciences that considers a range of sustainability factors and stakeholder perspectives while engaging students, faculty, and partners in design process for an expansive campus landscape. These authors referenced planning recommendations but were not explicit in how the framing of the project or their recommendations tied to specific campus plans or policies. It may be that these linkages were understood but not reported in the article.

5. Discussion

Our review set out to understand four questions about how living laboratories are applied to campus biophysical landscapes. Our discussion returns to these four questions while also providing recommendations for university policy or practice.

5.1. How are living labs defined when applied in contexts that utilize the biophysical landscape?

Campus landscapes function as learning laboratories through student and faculty engagement in place-based learning projects and environmental stewardship that promote sustainable thinking. As a framework, living laboratories provide opportunities to apply and practice sustainability principles in and outside the formal curriculum. In our review, the term living laboratory was collectively defined as a framework that uses the campus for applied and transdisciplinary research and teaching, co-creation, student engagement, and overall campus transformation in sustainability. Experiential learning theory, although not exclusive to the living laboratory framework, serves as a key concept where students learn through hands-on experiences, furthering their engagement on campus. This is consistent with the AASHE (2013) framing of living laboratories but is elaborated and given context through the publications in our review. Campus transformation is a central element of living laboratories in the context of the biophysical landscape. Our review identified the biophysical landscape as a living laboratory that provides opportunities:

- to *consider* ways to make the biophysical landscape more sustainable through research, outreach, design, planning, or policy
- to *implement* sustainable landscape practices through stewardship, garden installations, or other physical alterations of the biophysical environment
- to *demonstrate* existing sustainable landscape features through interpretation, demonstration gardens, and campus tours to communities or schools and/or
- to *generate new thinking* for ways the biophysical landscape can contribute to campus sustainability.

While many projects can utilize a campus' biophysical landscape, the living laboratory framework was often applied as a tool to generate new ideas about how to enact sustainability in a local context and to engage students in the process of innovation and ideation.

However, our review also identified the inconsistency in terms as a major limitation for understanding and articulating the approaches to and benefits from living laboratories on campus landscapes. Learning landscape, sustainable campus landscape, and adaptive co-management

are all used to describe various approaches that can be applied when incorporating the biophysical landscape within the living laboratory framework. Authors sometimes would employ one of these terms without explicitly providing clear definitions or underlying assumptions. Some would label their project a "living laboratory," with no exploration of what was meant by this concept. Based on our research, we generated definitions that draw from review article definitions and project descriptions (Fig. 1). We recommend more consistent employment of these terms in order to advance landscapes into living laboratory frameworks. The term *landscape as living laboratory* seems to reflect the intentions and potential of this framework when applied to campus lands and open spaces.

We also acknowledge that the term "learning landscape" and its variants have been employed to a large degree to describe digital platforms to engage learners, including in response to the COVID-19 pandemic. A cursory review in Google Scholar found thousands of references to learning landscapes in response to the pandemic that have no relation to the biophysical environment. For example, Osman (2020) described the "learning landscape" associated with e-learning and remote teaching; McVicar and Bullard (2021) described ways to continue experiential learning in health sciences during the pandemic using the term "virtual experiential learning landscape"; and Bergdahl and Nouri (2020) described research findings for the "learning landscape" of distance education during the pandemic itself. We therefore encourage future publications that are specifically aimed at understanding experiential learning with the *biophysical landscape* to employ "living laboratory" or "landscape as a living laboratory" and perhaps to include specific references to the *biophysical landscape* in keywords and abstracts.

5.2. How is the biophysical landscape integrated into living labs for teaching and learning?

Our review identified ways that sustainability is often taught through experiential education approaches, including field- and project-based learning (Colding & Barthel, 2017; Krasny & Delia, 2014; Tao et al., 2019; Zhang et al., 2016). Such approaches expose students to a range of knowledge and skills, including problem solving, collaboration, and social learning (Chambless et al., 2012; Hansen, 2012; Robbins et al., 2019; Tao et al., 2019; Wals, 2014; Zhang et al., 2016), governance and decision-making (Colding & Barthel, 2017; Tao et al., 2019; Wals, 2014), ecological systems and processes (Bergquist et al. 2019; Cheang et al., 2017; Colding & Barthel, 2017; Krasny & Delia, 2015; Zen, 2016), and green infrastructure (Tao et al., 2019; Way et al., 2012). Student engagement in research projects is part of the living lab framework (AASHE, 2013; CSU, n.d.; University of Minnesota, 2021; UC Davis, 2021), but is less clearly or consistently identified in the literature we reviewed.

Projects in our review engaged most consistently with sciences, engineering, and environmental design professions. This makes sense for campus landscapes, but sustainability is broad and interdisciplinary, and could include other project types, that bring culture and social settings together with campus sustainability, for example, or that link history of place to the campus. Integration of Indigenous gardens into service learning at the University of Nebraska Omaha (Robbins et al., 2019) is one direct example of this from our review. Two additional projects engaged ideas of interpretation of the landscape campus (Barlett, 2002; Savanick et al., 2008). Other disciplinary foci are also possible. For example, Smith and Spencer (2012) documented how students in a preservation planning course engaged the broader student body to develop planning recommendations for both campus buildings and open space.

Psychology and the health sciences are also disciplines that could explore the restorative benefits of campus landscapes in stress reduction. Some articles in our review focused on student wellness as linked to campus landscapes (Hipp et al., 2016; Krasny & Delia 2014; Robbins et al., 2019; Speake et al., 2013), but this is of growing importance (Foellmer et al., 2021; Lu & Fu, 2019) and is perhaps an underdeveloped aspect of social sustainability practices in connection to living laboratories. Like a previous review that focused on biophilic campus spaces for health (Peters & D'Penna, 2020), we have found more studies that focused on health and wellness by engaging students through surveys or other research methods *as subjects* rather than *as agents of change* for their campus, which could occur through living laboratory frameworks. The article by Speake and colleagues (2013) that was part of our scoping review demonstrated a possible way to begin engaging students in discussions about campus greenspaces for health promotion when they described a focus group discussion in which students elaborated key issues raised from an earlier, more broadly issued, questionnaire. The focus group process helped identify a variety of ways that existing campus spaces were effective in health promotion as well as ways that the experience of campus could be improved, such as through better identification of pathways and incorporation of signs and interpretation. These recommendations could then lead to student engagement with the campus as a living laboratory, through revisions to campus landscape or sustainability policy or through actual transformation of the campus biophysical landscape. Work by Seitz and colleagues (2014) demonstrated another model for engaging students in thinking about restorative greenspaces through the use of photovoice on campus.

Campus landscapes as living laboratories could engage more disciplines and thereby engage more of its students directly into sustainability practices. The broad framing that Thomashow (2014) provides could be a useful way to consider the potential of the campus landscape for transformation more systematically, by considering how the campus as a whole engages with infrastructure (energy, materials, and food), community (governance, investment, and wellness), and learning (curriculum, interpretation, and aesthetics). In particular, our review suggests more living laboratories could engage with governance, wellness, and interpretation.

5.3. How are students engaged in the process of designing and learning about the biophysical landscape within living labs?

In our review, learning landscapes and co-management approaches were the two domains that consistently sought to engage students whereas sustainable campus planning was less consistent. Some of the projects in our review saw students as stakeholders in the use of spaces and engaged with them through interviews and surveys about sustainable campus landscapes (Li, Ni, & Dewancker, 2019; Speake et al., 2013) but did not explore on-going and iterative frameworks that co-management practices imply. Other sustainable campus landscape projects in our review did not explicitly engage students at all or only briefly mentioned that students are connected to projects given in an overview (Franklin et al., 2003; Kurtaslan, 2020; Misni et al., 2020; Oyama et al., 2018; Parker, 2006; Roman et al., 2017). As some review articles have asserted, some campuses are engaging in transformation of the campus as a sustainable landscape but losing the opportunity to engage students and faculty in meaningful ways (Savanick et al., 2008).

Many projects in our review seem to demonstrate a disconnect between the social aspects of sustainability and the physical environment. Co-management came the closest to bringing these together. Student involvement in these cases could be used to influence policy, planning, and management of spaces. Erixon Aalto et al. (2018) specifically articulated the need for transdisciplinary collaboration to create cycles of participation, learning, and doing through the processes of adaptive co-management. The design professions have a long history of participatory engagement of students and community (de la Peña et al., 2017), even if this practice is still not mainstream (Kempenaar, 2021). These practices also could be applied more consistently to engagement of students in landscapes as living laboratories.

5.4. How do biophysical landscapes as part of living labs fit into a campus's broader sustainability goals?

Linkages between campus sustainability plans and specific projects often were not clear, particularly for learning landscapes. Our review identified 14 papers (50%) that connected project goals to campus sustainability goals or values. Of these, three discussed connections to policies and plans in detail and two provided critiques that these connections were not more strongly made in living laboratory projects. If projects are not clearly linked to longer term plans and goals, then they run the risk of falling into the ad-hoc management described for community gardens (Marsh et al., 2020), and may potentially lack long term impact or risk losing support when faculty or student leaders move on, as Cheang et al. (2017) described for their campus. It is also possible that these linkages are made, but articles are not making this explicit. Greater attention to these relationships is important not only so that living laboratories begin to operate in a systematic way across the university campus but also so that other campuses can see how the living laboratory is linked to broader campus institutions and practices for sustainability. Evans et al. (2015) described a living lab at the University of Manchester in which they viewed the living laboratory concept as a systematic approach to student engagement both across and within the surrounding community. Their work did not appear in our review search but provides a useful model for whole campus applications of the living lab concept across multiple disciplines and project types at a single university.

The utilization of landscapes as spaces for health promotion also is an increasingly pressing goal for public spaces and universities (Collins et al., 2020; Foellmer et al., 2021; Gulwadi, Mishchenko, Hallowell, Alves, & Kennedy, 2019; Hipp et al., 2016; Lu & Fu, 2019; McFarland et al., 2008; Speake et al., 2013). Natural landscapes on campuses provide opportunities to bridge sustainable development goals (United Nations, n.d.) that we found to be less often a part of landscapes as living laboratories; these include Goal 2: Eliminating Hunger, through food gardens on campus, and Goal 3: Good Health and Well-Being, through natural spaces that promote physical activity and mental restoration. In addition, Opdam (2020) promotes collaboration in the establishment of sustainable landscapes to support human health. Landscapes as living laboratories are one means to achieve this. In our review, Robbins et al. (2019) provided explicit linkages between demonstration gardens and Indigenous health and lifeways. However, our review found that while the concept of campus landscapes for human health promotion is emerging, explicit connections between health and student engagement in landscapes as living laboratories were not widely made.

6. Conclusion

Landscapes as living laboratories on college campuses can be valuable sites for teaching, learning, and sustainable transformation, generating new thinking about how we inhabit the world. The living laboratory framework offers great potential to explicitly bridge planning for sustainable campus landscapes in teaching, research, and co-management. These approaches reflect the ideas of innovation and campus transformation through experiential learning. Many projects that employed the frame of a living laboratory involved multiple colleges or departments within a university, working across disciplines to include campus stakeholders in generating new thinking for how to develop a sustainable campus. Students have been engaged in design, planning, installation, stewardship, and management of campus landscapes through courses, research, and co-curricular activities. Our review identified that the majority of projects engaged with landscapes as living laboratories through environmental science, design, and other allied disciplines. Other disciplines, such as health sciences or education, could also engage with living laboratories to engage students in sustainability. Our review also found that projects could more explicitly connect faculty and student engagement with broader campus sustainability goals and plans. The use of consistent language and application of terms would allow for a deeper understanding of approaches and processes and may help other universities to determine the best actions for their campus when incorporating landscapes into living laboratories. Many of the projects identified through our review were descriptive in nature. Future research also could assess the benefits that come from utilization of landscapes as living laboratories for student learning, health, and sense of belonging; student identification of career pathways; student, faculty, and staff satisfaction and retention; and impacts to campus sustainability itself.

References

*Citations with an *asterisk were part of the scoping review.*

Backman, M., Pitt, H., Marsden, T., Mehmood, A., & Mathijs, E. (2019). Experiential approaches to sustainability education: Towards learning landscapes. *International Journal of Sustainability in Higher Education, 20*(1), 139–156. https://doi.org/10.1108/IJSHE-06-2018-0109

*Barlett, P. F. (2002). The Emory University campus walking tour: Awakening a sense of place. *International Journal of Sustainability in Higher Education, 3*(2), 105–112. https://doi.org/10.1108/14676370210422339

Bergdahl, N., & Nouri, J. (2020). Covid-19 and crisis-prompted distance education in Sweden. Technology, Knowledge and Learning, 1-17.

*Bergquist, D., Hempel, C. A., & Green, J. L. (2019). Bridging the gap between theory and design. *International Journal of Sustainability in Higher Education, 23*(3), 548–567.

Bruce, J. L. (2011). Revealing campus nature: The lessons of the native landscape for campus heritage planning. *Planning for Higher Education, 39*(3), 179–189.

California State University [CSU]. (n.d.). "Campus as a Living Lab" program. https://www2.calstate.edu/impact-of-the-csu/sustainability/Pages/Campus-as-a-Living-Lab.aspx.

*Calkins, M. (2002). Assignment: eco-friendly campuses. Landscape Architecture, 92(7), 38,40,42-43,90-91.

*Chambless, R., Parvaz, A., Chesson, L. A., & Ruff, J. S. (2012). University of Utah campus gardens: A living laboratory for sustainability. *Sustainability: The Journal of Record, 5*(3), 160–164.

*Cheang, C. C., So, W. M. W., Zhan, Y., & Tsoi, K. H. (2017). Education for sustainability using a campus eco-garden as a learning environment. *International Journal of Sustainability in Higher Education, 18*(2), 242–262.

*Colding, J., & Barthel, S. (2017). The role of university campuses in reconnecting humans to the biosphere. *Sustainability, 9*(12), 1–13.

Collins, R. M., Spake, R., Brown, K. A., Ogutu, B. O., Smith, D., & Eigenbrod, F. (2020). A systematic map of research exploring the effect of greenspace on mental health. *Landscape and Urban Planning, 201*, 103823. https://doi.org/10.1016/j.landurbplan.2020.103823

Davis, J. (2012). *The first generation student experience: Implications for campus practice, and strategies for improving persistence and success*. Stylus Publishing, LLC.

De la Peña, D., Jones Allen, D., Hester, R. T., Hou, J., Lawson, L. J., & McNally, M. J. (Eds.). (2017). *Design as democracy: Techniques for collective creativity*. Island Press.

*Erixon Aalto, H., Marcus, L., & Torsvall, J. (2018). Towards a social-ecological urbanism: Co-producing knowledge through design in the Albano Resilient Campus Project in Stockholm. *Sustainability, 10*(3), 717. https://doi.org/10.3390/su10030717

Evans, J., Jones, R., Karvonen, A., Millard, L., & Wendler, J. (2015). Living labs and co-production: University campuses as platforms for sustainability science. *Current Opinion in Environmental Sustainability, 16*, 1–6.

Felsten, G. (2009). Where to take a study break on campus: An attention restoration theory perspective. *Journal of Environmental Psychology, 29*(1), 160–167. https://doi.org/10.1016/j.jenvp.2008.11.006

Filho, W.L., Salvia, A.L., Pretorius, R.W., Londero Brandli, L., Manolas, E., Alves, F., Azeiteiro, U., Rogers, J., Shiel, C., & Do Paco, Arminda (Eds.). (2020). Universities as Living Laboratories for Sustainable Development: Supporting the Implementation of Sustainable Development Goals. Springer.

Foellmer, J., Kistemann, T., & Anthonj, C. (2021). Academic greenspace and well-being: Can campus landscapes be therapeutic? Wellbeing, Space and Society (2). doi: 10.1016/j.wss.2020.100003.

Fors, H., Jansson, M., & Nielsen, A. B. (2018). The impact of resident participation on urban woodland quality—a case study of Sletten, Denmark. *Forests, 9*(11), 1–20. https://doi.org/10.3390/f9110670

*Franklin, C., Durkin, T., & Schuh, S. P. (2003). The role of landscape in creating a sustainable campus. *Planning for Higher Education, 31*(3), 142–149.

*Genta, C., Favaro, S., Sonetti, G., Barioglio, C., & Lombardi, P. (2019). Envisioning green solutions for reducing the ecological footprint of a university campus. *International Journal of Sustainability in Higher Education, 20*(3), 423–440.

Gustavsson, R., Gunnarsson, A., & Wiström, B. (2019). Thirty years of experiences from outdoor landscape teaching. In K. Jørgensen, N. Karadeniz, E. Mertens, & R. Stiles (Eds.), *The Routledge handbook of teaching landscape*. Routledge Press.

Gulwadi, G. B., Mishchenko, E. D., Hallowell, G., Alves, S., & Kennedy, M. (2019). The restorative potential of a university campus: Objective greenness and student perceptions in Turkey and the United States. *Landscape and Urban Planning, 187*, 36–46. https://doi.org/10.1016/j.landurbplan.2019.03.003

*Hansen, G. (2012). When students design learning landscapes: Designing for experiential learning through experiential learning. *NACTA Journal, 56*(4), 30–35.
*Hipp, J. A., Gulwadi, G. B., Alves, S., & Sequeira, S. (2016). The relationship between perceived greenness and perceived restorativeness of university campuses and student-reported quality of life. *Environment and Behavior, 48*(10), 1292–1308.
Kempenaar, A. (2021). Learning to design with stakeholders: Participatory, collaborative, and transdisciplinary design in postgraduate landscape architecture education in Europe. Land 2021, 10(3), 243. doi: 10.3390/land10030243.
Krasny, M. E., & Delia, J. (2015). Natural area stewardship as part of campus sustainability. *Journal of Cleaner Production, 106*, 87–96.
*Krasny, M. E., & Delia, J. (2014). Campus sustainability and natural area stewardship: Student involvement in adaptive comanagement. *Ecology and Society, 19*(3), 27.
*Kurtaslan, B. O. (2020). Examination of Selcuk University Alaaddin Keykubat Campus in the context of ecological landscape design. *Journal of Environmental Biology, 41*(2 (SI)), 463–474.
*Li, X., Ni, G., & Dewancker, B. (2019). Improving the attractiveness and accessibility of campus green space for developing a sustainable university environment. *Environmental Science and Pollution Research, 26*(32), 33399–33415.
Lu, M., & Fu, J. (2019). Attention restoration space on a university campus: Exploring restorative campus design based on environmental preferences of students. *International Journal of Environmental Research and Public Health, 16*, 2629. https://doi.org/10.3390/ijerph16142629
Marsh, P., Mallick, S., Flies, E., Jones, P., Pearson, S., Koolhof, I., et al. (2020). Trust, connection and equity: Can understanding context help to establish successful campus community gardens? *International Journal of Environmental Research and Public Health, 17*(20), 7476. https://doi.org/10.3390/ijerph17207476
Martin, F. E. (2011). The puzzles and promise of campus landscape preservation: Integrating sustainability, historic landscapes, and institutional change. *Planning for Higher Education, 39*(3), 167–178.
*Misni, A., Razmi, N. M., Ahmad, P., Kamaruddin, S. M., Rasam, A. R. A., & Nor, R. M. (2020). Applying low carbon landscapes at the Premier Polytechnic of Sultan Salahuddin Abdul Aziz Shah, Shah Alam, Malaysia. *International Journal of Environment and Sustainable Development, 19*(3), 284–294.
Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1), 1–7. https://doi.org/10.1186/s12874-018-0611-x
McFarland, A. L., Waliczek, T. M., & Zajicek, J. M. (2008). The relationship between student use of campus green spaces and perceptions of quality of life. *HortTechnology, 18*(2), 232–238. https://doi.org/10.21273/HORTTECH.18.2.232
McVicar, K. L., & Bullard, G. L. (2021). Maintaining experiential learning continuity and integrity during a global pandemic. *Journal of Health Administration Education, 38*(1), 351–362.
O'Keeffe, P. (2013). A sense of belonging: Improving student retention. *College Student Journal, 47*(4), 605–613.
Opdam, Paul (2020). Implementing human health as a landscape service in collaborative landscape approaches. *Landscape and Urban Planning, 199*, 103819. https://doi.org/10.1016/j.landurbplan.2020.103819
Ou, W. S., Lin, Y. F., Jing, S. R., & Lin, H. T. (2006). Performance of a constructed wetland-pond system for treatment and reuse of wastewater from campus buildings. *Water Environment Research, 78*(12), 2369–2376.
Osman, M. E. (2020). Global impact of COVID-19 on education systems: The emergency remote teaching at Sultan Qaboos University. *Journal of Education for Teaching, 46*(4), 463–471.
*Oyama, K., Pasquier, A. G., & Mojica, E. (2018). Transition to sustainability in macro-universities: The experience of the National Autonomous University of Mexico (UNAM). *Sustainability, 10*(12), 4840. https://doi.org/10.3390/su10124840
Pallot, M., Trousse, B., Senach, B., & Scapin, D. (2010, Aug.). Living lab research landscape: from user centred design and user experience towards user cocreation. [Presentation]. First European Summer School "Living Labs," Inria (ICT Usage Lab), Userlab, EsoceNet, Universcience, Paris, France.
*Parker, J. (2006). The botanic garden of the university of Cambridge. *SiteLINES: A Journal of Place, 2*(1), 10–11.
Peters, T., & D'Penna, K. (2020). Biophilic design for restorative university learning environments: A critical review of literature and design recommendations. *Sustainability, 12*(17), 7064.
*Rieske, L. K., Borden, S., Damron, B., Williamson, N., Arthur, M., & Kinney, A. (2019). College campus as a living laboratory: Scrubbing scales, saving trees, engaging students. *American Entomologist, 65*(1), 43–49.
*Robbins, R. E., Robbins, T. R., & Frailey, M. (2019). Campus-based ecotourism: A case study on the power of local ecotourism. *Great Plains Research, 29*(2), 107–121.
*Roman, L. A., Fristensky, J. P., Eisenman, T. S., Greenfield, E. J., Lundgren, R. E., Cerwinka, C. E., et al. (2017). Growing canopy on a college campus: Understanding urban forest change through archival records and aerial photography. *Environmental Management, 60*(6), 1042–1061.
*Savanick, S., Strong, R., & Manning, C. (2008). Explicitly linking pedagogy and facilities to campus sustainability: Lessons from Carleton College and the University of Minnesota. *Environmental Education Research, 14*(6), 667–679.
Seitz, C. M., Reese, R. F., Strack, R. W., Frantz, S., & West, B. (2014). Identifying and improving green spaces on a college campus: A photovoice study. *Ecopsychology, 6*(2), 98–108.
*Shriberg, M., & Harris, K. (2012). Building sustainability change management and leadership skills in students: Lessons learned from "Sustainability and the Campus" at the University of Michigan. *Journal of Environmental Studies and Sciences, 2*(2), 154–164.
*Smith, G. R. (2012). Environmental education + learning landscapes. *The Agricultural Education Magazine, 84*(5), 22–23.
*Smith, A. L., & Spencer, M. (2012). A DIY campus preservation plan: Lessons learned at the University of Mary Washington. *Planning for Higher Education, 40*(2), 5–12.
*Speake, J., Edmondson, S., & Nawaz, H. (2013). Everyday encounters with nature: Student perceptions and use of university campus green spaces. *Human Geographies: Journal of Studies & Research in Human Geography, 7*(1), 21–31.
*Tao, Z., Newman, G., Arnold, M., Li, M. H., & Kim, J. H. (2019). The living green infrastructure lab: Advancing interdisciplinary teaching and experiential learning in landscape architecture pedagogy. *Landscape Research Record, 8*, 75–86.
Thomashow, M. (2014). The nine elements of a sustainable campus. Sustainability: The Journal of Record, 7(3), 174-175.
*Tittley, E. (2000). Greening the Ivory Tower. Alternatives Journal, 26(3), 34-34.
University of California, Davis. (2021). Learning by leading. https://arboretum.ucdavis.edu/learning-by-leading.
University of Minnesota. (2021). Living lab. https://italladdsup.umn.edu/get-involved/living-lab.
United Nations (n.d.). The 17 goals. Department of Economic and Social Affairs: Sustainable Development. https://sdgs.un.org/goals.
Wals, A. E. (2014). Sustainability in higher education in the context of the UN DESD: A review of learning and institutionalization processes. *Journal of Cleaner Production, 62*, 8–15.
Wals, A. E., & Blewitt, J. (2010). Third-wave sustainability in higher education: Some (inter) national trends and developments. In P. Jones, D. Selby, & S. R. Sterling (Eds.), *Sustainability education* (pp. 70–89). Routledge Press.
Way, T., Matthews, C., Rottle, N., & Toland, T. R. (2012). Greening the American campus: Lessons from campus projects. *Planning for Higher Education, 40*(2), 25–47.
*Zen, I. S. (2016). Exploring the living learning laboratory: An approach to strengthen campus sustainability initiatives by using sustainability science approach. *International Journal of Sustainability in Higher Education, 18*(6), 939–955.
*Zhang, Z., Zhou, J., Schmidt, D., & Garland, K. (2016). Sustainable campus landscapes in the United States and China: A comparative analysis. *Geographical Bulletin, 57*(1), 41–61.