Engaging students in redesigning a local urban space to improve ecosystem services

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Abstract
Ecosystem services are an important, but often invisible component of the urban landscape. Humans have altered the environment in cities, leading to degraded or missing ecosystem services in many cases. To enhance or replace these services, many urban municipalities are integrating green spaces and infrastructure into urban planning. We have designed an activity to help undergraduate students: 1) recognize the importance of urban ecosystem services, 2) identify when they are degraded or missing, and 3) integrate “green” ideas from multiple sources to propose improvements to them. To help students achieve these goals, we asked them to evaluate an underutilized space on their own campus, and propose a redesign of that space to support ecosystem services. While many students struggled initially to link urban ecosystem services with specific proposed improvements, we found that having students work together in groups for a second redesign often improved understanding and also resulted in more creative and interdisciplinary designs. The exercise also helped students to better identify ecosystem services and allowed them to practice integrating multiple viewpoints while proposing solutions to local environmental problems.

Keywords Active learning · Urban ecology · Ecosystem services

Introduction
Ecosystem services are benefits that humans receive from ecosystems. People living in urban areas depend on ecosystem services both within their boundaries and from surrounding areas. Locally generated services have substantial impacts on human health and quality of life, and planning is essential for their preservation and restoration (Boland and Hunhammar 1999; Woodruff and BenDor 2016; Cortinovis and Davide 2018). Ecosystem services have been categorized in a variety of ways (Daily 1997; World Health Organization 2005; Gomez-Baggethun et al. 2013; Elmqvist et al. 2015), but most organizational systems focus on four main groupings: provisioning, regulating, supporting and cultural. Each of these types of ecosystem services are impacted by human activities and thinking about different categories of services can provide a cognitive framework for understanding and exploring what may be missing or degraded within an urban area.

Urban ecosystems tend to be highly modified by humans, with consequent reductions in many of the services provided to humans (Douglas and James 2015). Biodiversity and ecosystem complexity are especially altered, with many urban ecosystems left vulnerable to perturbations (both natural and anthropogenic) and potentially less resilient in the face of changes (World Health Organization 2005; Ahem 2011; McPhearson et al. 2015). Human interventions in the form of land-use planning, management, conservation and restoration are often needed to improve lost or degraded ecosystem services and counteract ecosystem disservices (Shackleton et al. 2016; Larson et al. 2019). Ecosystem disservices encompass the negative impacts of natural systems and processes on human well-being, and are a currently debated topic in environmental literature (see Blanco et al. 2019).

In urban areas, services and disservices that directly impact human health and well-being are particularly important. For example, as land-use change and global climate change continue to advance, urban ecosystem services are needed to mitigate the effects of warming through green infrastructure in the form of green roofs, street trees, and parks (Bowler et al. 2010; Li et al. 2017). Additionally, these green areas provide air purification, noise reduction...
and contribute to a sense of place (Nowak et al. 2006; Peters et al. 2010; Dzhambov and Donka 2015). To many humans, these ecosystem services are invisible and undervalued, and are only noted in their absence.

Including urban ecosystem services in college classes should be prioritized to better educate students about their potential future contributions to the greening of urban areas. To illustrate ecosystem services to students and involve them in the planning process, we have designed activities to help students actively explore their own roles in the urban environment, and to “see” the invisible services that surround them. To increase students’ awareness of ecosystem services, particularly in a built environment they are familiar with, this activity asks them to examine a space on their campus and develop plans to redesign it to increase ecosystem services and decrease ecosystem disservices. Students identify missing or degraded services and then propose changes to enhance services. They then write proposals, exchange ideas, and re-reflect on their proposals. These written assignments and reflections highlight the importance of the invisible ecosystem services and reinforce the importance of viewing urban areas through an ecosystem lens. The activity helps students recognize relationships between human well-being and urban environments, and specifically illustrates the concept of feedback relationships in which humans affect the environment through design and the environment that in return affects human well-being. The activity also asks them to reflect on the importance of involving community partners in the design and upkeep of urban green spaces (Rademacher et al. 2019).

Learning outcomes

After completing this activity, students should be able to:

- Describe ecosystem services and disservices, and explain their importance to humans
- Identify both global and local threats to ecosystem services, particularly in urban settings
- Discuss how humans modify and impact ecosystem services in urban areas and how planning can minimize or eliminate negative human impacts and disservices, and enhance beneficial impacts
- Identify present and absent ecosystem services in a local urban landscape and suggest strategies and actions to manage, restore, or enhance targeted ecosystem services
- Activity requires a minimum of 50 minutes in one class setting, or longer split over two class periods (depending on location of targeted area), with the written assignment done afterwards as homework. Optional additional drafts and/or group work may also be done over subsequent weeks.
- Requires no student background knowledge
- Adaptable to classes of any size
- Could be used in introductory courses in: Environmental Science/Studies, Ecology, Sustainability Studies, or Geography

Instructor preparation and materials

The instructor pre-identifies an area of the local campus or nearby urban area that is underused, poorly designed, or neglected to target for re-design. If visiting the area is desirable within the same class period as the introductory lecture, the area should be nearby. Alternatively, the instructor could have the visit occur in a separate class meeting. The instructor could take photos of the site to include in the presentation, but this is not essential. The area does not need to be a specific size, but rather should be a place in need of improvement for both use by humans and restoration of ecosystem services. For example, we have identified a neglected quadrangle between two buildings that has poor drainage, plantings of non-native species, poor aesthetics, and a steep slope on one side with offices on the others. Most students do not even know the area exists.

To carry out this activity, the instructor will need to provide a 20 to 30 minute overview on ecosystem services, to (A) describe what they are and why they are important, (B) describe the threats and challenges to ecosystem services, particularly in urban environments, and (C) lead a discussion of what types of services might be present, degraded, or absent from the campus or surrounding urban environment. This overview could be done in a classroom space or on-site when the class visits the space to be redesigned. Good resources for information about humans and urban ecosystem services include: the ecosystem services chapter of Urban Ecology by Douglas and James (2015), Costanza et al. (2014) updated paper on the value of ecosystem services; Kubiszewski et al. (2017), the Millennium Ecosystem Assessment (World Health Organization 2005), the ecosystem services chapter of Sustaining Life (Melillo and Sala 2008), or most Environmental Science textbooks. An additional resource is the Campus Ecology program of the National Wildlife Federation (2020). Campus or local area maps, digital aerial photos, and satellite imagery of the campus over time are also useful to illustrate pre and post campus development and may be useful to students to illustrate the

Course context

- Originally designed for an Urban Ecology course for 10-16 students, with a mix of sophomore undergraduate to graduate students from a variety of majors (course described in Hane and Korfmacher 2020)
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chosen study location. Use Google Earth, ESRI’s Living Atlas and ESRI’s Green Infrastructure Project (ESRI 2020a, b) for digital imagery and maps to launch this discussion.

Additionally, the instructor will need to prepare a written prompt for the students to respond to for their writing assignment. The specific prompt we have used for what the students should reflect on and turn in is included in Box 1. If desired, additional concepts could be added, including asking the students to reflect on opportunities for community engagement. The written instructions provide a record for students to refer back to, and includes explanations of what the assignment is about and what they should turn in and when. An example of a student response is included in the Supplementary Materials.

Box 1:

Example of assignment text that is specific to our campus:

In an effort to become more sustainable and incorporate more ecological functions and services, Rochester Institute of Technology has been converting areas on campus that have plantings of invasive or non-native species and turning them into “green” spaces. Examples include some of the rain garden features by the library bus circle, the community garden plot, and the S-Lot wetlands.

Your task is to redesign a largely unused courtyard between Ross Hall (Bldg 10) and Color Science (“Link Building”) that we visited in class. Its main purpose now is to serve as the parade grounds for ROTC ceremonies (and they may not want to give this area up without a fight). You have approximately 1,100 m² to work with. Dr. Korfmacher’s office looks out on this courtyard, but he is not your only “client”. Right now, there’s English ivy, brick, turf/lawn, a “rose garden”, and a few trees/shrubs planted in the area. It is mostly flat, but there is a significant slope along the western edge that contributes runoff to the poorly drained parade ground. Feel free to revisit the area if you want to get a better sense of what’s currently there.

What would you do with this area? Describe your plan in detail (drawings/maps/photos are welcomed and encouraged). In an accompanying essay (2 pages), describe (1) how your ideas contribute to campus sustainability, focusing on the ecosystem services they provide or restore; and 2) how your ideas will be used by and benefit people in the larger community.

Learning activities

After the introduction (20-30 minutes), the instructor and students visit the space that will be redesigned. Alternatively, the presentation may be given while on site to reduce travel time and to incorporate examples from the specific environment. The instructor should allow the students to explore the space making general observations and taking notes (5-10 min), then should lead a discussion about how it is currently used and its ecological characteristics. Key questions might include: 1) Who uses this space and how and when is it used? 2) What ecosystem services and disservices exist here? What is missing or degraded? 3) What are the plants, soil, water and built features in this area, and are they desirable in terms of aesthetics, services and sustainability? If time allows, the instructor may also want to prompt students to think about who is in charge of planning and maintaining these areas and how proposals are processed on their campus. Involving key campus planners as part of this exercise adds complexity, but a real world element as well, as successful urban green space planning includes community involvement. Depending on the mixture of students in the course, the instructor may also want to address the idea of multifunctionality, and how adding one service may detract from others (e.g. Hansen and Pauleit 2014). At the end of the discussion, students are given the written assignment that explains what should be turned in.

Students turn in their plans and essays, and the instructor provides feedback, focusing particularly on ecosystem services and how they are represented in the plans for improving the area. If a second iteration of design is included in the class, students are then encouraged to form groups to work on the next version of the plans, integrating their expertise and debating the relative merits of their plans. This may be done in class or outside of class as a homework assignment.

Extensions and additional connections

Additional activities or topics could be added or extended, depending on the overall emphasis and learning outcomes of the course. For us, working in groups and finding ways to integrate multiple viewpoints/disciplines was a main goal, but courses with students from a single discipline or with more advanced backgrounds may find other topics or activities enriching. Here are a few suggestions:

- Ask the students to build a budget for the improvements that they are considering. Be sure to consider upkeep by building and grounds personnel, who will likely be tasked with maintaining any plantings or structures. If possible, budget justifications should include a cost benefit analysis, to help make the economic case for these ecological improvements (often a limiting factor, but demonstrating a reasonable payback period
helps). If desired, the instructor could give the students a budget cap.

- Brainstorm with students about who would need to be involved to make their changes, such as buildings and grounds personnel and any oversight committees. Can these improvements be integrated in other courses or service projects? What other groups on campus have a stake in this area, or might be able to meaningfully contribute? How should they be included?

- Consider whether small grants on campus are available for student projects, and if so have the students write a grant proposal to fund some of their ideas for improving the location on campus.

- Ask students to think about the public spaces in their hometown or in a nearby city. What other spaces could be redesigned to include more ecosystem services? Who owns these spaces and how are they currently used? What would need to be done to involve local citizens in a redesign that incorporated more ecosystem services into urban public spaces? Who makes the decisions about how the space is used, and do they currently involve local citizens in those decisions? What is that decision making process and is it equitable to all stakeholders?

- Advanced classes could include more complex topics as the class allows, such as examining the use of non-native species in promoting ecosystem services (Schlaepfer et al. 2011), approaching the topic through the lens of biogeochemistry (Pataki et al. 2011), or a more thorough examination of ecosystem disservices (Campagne et al. 2018; Blanco et al. 2019).

- This lesson can be used to support additional topics in the course or in associated courses, such as environmental health, conservation biology, plant biology, hydrology or geographical information systems.

Reflections and conclusions

Students often have good suggestions for how to make the space more sustainable or green, but have a harder time tying their plans to ecosystem services directly. First drafts often lack details such as specific native plants and a consideration of the light, moisture and soil requirements needed to establish native plant communities. Often, students don’t try to integrate ideas to address multiple ecosystem services, such as combining improved drainage systems with bioswales to enhance biodiversity and provide habitat, or pairing solar panels and bug hotels with green roofs to optimize space and integrate functions. Comments from instructors on the first draft of student work can help push students towards examining services more directly (e.g. they will often include a feature, but not say what ecosystem service(s) it enhances), and our experience has been that the second draft is often improved in this area. If time allows, a second draft where students work together in teams is recommended to help students better develop their ideas and draw on the strengths of different majors.

Depending on the backgrounds and past experiences of the students, they will bring various perspectives and knowledge to the exercise. For example, art and design students may bring expertise in design, lighting, and use of space (e.g. drawings, plans, textures, etc.), while environmental science students may focus on specific species for plantings or gardens, soil and ground cover, while engineers may prioritize technological solutions (e.g. solar panels, structures or drainage solutions). Students may find their proposed changes conflict with other proposals, restrict current use of the space, or exacerbate existing problems, leading to discussions and adaptations. Thus, the second draft draws more collectively on the expertise of the group and explores tradeoffs. The revisions often are more appreciative of the diversity, complexity, and connectedness of various ecosystem services and disservices because students see and incorporate each other’s work and link initiatives to try and maximize (and justify) the number of services provided (see Supplement 1 – Student project example).

Benefits of this assignment to student understanding have appeared in later work in our course. Having critically thought about and researched how to enhance a specific local area, our students have engaged in more enriched discussions about ecosystem services represented in an area when we go on field trips or examine case studies. This assignment in particular has directly enhanced subsequent written assignments. For example, the final project of the course (Storymaps focusing on specific aspects of urban ecology) integrates multiple environmental, social and cultural components in the examination of a sustainability issue (see Hane and Korfmacher 2020 for details). Students draw from their redesign project to envision how issues might involve solutions that address multiple ecosystem services while also appreciating the specific needs of local communities.

Overall, we have found that this activity helps students “see” ecosystem services within the urban environment, and gives them practical ideas about the process by which those services might be enhanced through human interventions. They also benefit from exposure to alternative viewpoints, and finding ways to integrate those multiple ideas into a shared vision. Rather than being a theoretical or abstract idea, ecosystem services thus takes on a personal meaning when students experience the green space themselves, and have a role in improving the environment they live in.

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Declarations

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Consent for publication N/A.

Conflicts of interest/competing interests None.

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