Incorporating Systems Thinking: A Core Strategy for University Impact

Recommendations from a workshop

Potomac Science Center
George Mason University
November 11, 2022

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Photo courtesy of Jeremy Campbell.

Executive summary

Understanding our increasingly interconnected world requires systems thinking–the ability to recognize how everyday phenomena emerge from interactions within complex systems composed of people, nature, and the planet on which we live. Systems thinking skills and approaches support George Mason University's strategic vision for achieving impact through educational programs that promote interdisciplinarity, recognize diverse perspectives, and engage communities. Yet, despite their relevance to the institution's goals, they remain at the periphery of these discourses.

This report describes findings from a daylong workshop in November 2022 in which Mason faculty, staff, and students described current approaches to teaching systems thinking and examined some of the challenges they face in doing so. Participants proposed the following recommendations to support system thinking pedagogy:

1. Creation of a Stearns Center Level 1 credential workshop, or sequence of workshops, on teaching systems thinking
2. Formation of a Faculty Learning Community on systems thinking
3. Development of university online web resources
4. Funding by the Office of the Provost for team teaching grants that explicitly include community engagement and civic learning components
5. Addition of a general education systems thinking course option for the Mason Core quantitative reasoning requirement
6. Utilization of the university's campuses as living labs to demonstrate systems dynamics and systems thinking approaches

Systems thinking: A key component of interdisciplinary research and education to address global challenges

George Mason University's [2023 Strategic Direction] prioritizes ground-breaking research, innovative student learning experiences, and social impact from local to global scales that rise to the grand challenges of our time and "leave a healthier planet and people, thriving economies, and more just societies to the generations to come" (GMU, 2023). Important challenges like climate change and racism are known as "wicked" problems because they emerge from the complexity of countless causal chains that stretch across vast unbounded systems (Rittel & Webber, 1973). As a result, no single discipline can lay sole claim to the academic expertise needed to formulate the problem and its solution. In the face of scientific uncertainty, people's values and perspectives drive policy discourses, which are often conflicted and controversial.

Mason's vision recognizes that in order to address our most important problems, the institution must invest within its educational and research portfolios in building interdisciplinarity, recognizing diverse perspectives, and engaging communities (GMU, 2023). **Currently *unstated* in the university's strategic direction is that systems thinking skills and approaches are required to achieve these outcomes.** Meeting global challenges requires systems thinking (OECD & IIASA, 2020). This report details recommendations from a workshop on systems thinking that took place in November 2022 at Mason's Potomac Science Center, which was attended by faculty, staff, and students from across the university (Appendix A).

Defining systems thinking

Whereas traditionally research and education have focused on linear relationships of cause and effect, many of the world's problems behave in non-linear ways, subject to feedback loops and interactions with other parts of the system (Meadows, 2009). Systems thinking approaches manifest across a wide array of disciplines, from business management and the social sciences, to engineering, mathematics, and the natural sciences (Hossain et al., 2020). Systems thinking underlies the way environmental issues have been conceptualized since the 1970s (Meadows & Club of Rome, 1972; Ostrom, 2009); supports the design of engineered systems (Mohebbi et al., 2020; Shortle et al., 2018); and contributes to an understanding of racism and potential interventions to improve social equity (Watson & Collins, 2022).

Between 1991 and 2018, the systems thinking literature grew exponentially (Hossain et al., 2020). Across these fields systems thinking commonly entails: 1) characterizing non-linear relationships and dynamic behavior; 2) recognizing the whole as more than just its parts; 3) acknowledging interconnections; and 4) identifying stocks, flows, and feedback loops (Arnold & Wade, 2015). At the highest level of mastery, systems thinking is more than just describing conceptual models, but creating simulations and testing policies (Stave & Hopper, 2007).

Systems thinking and sustainability

Over its 50-year history, Mason has repeatedly committed to supporting sustainability--i.e., “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (WCED, 1987). Achieving sustainability requires the management of human-environment interactions within systems at local to global scales to ensure that dangerous thresholds are not surpassed (Berkes et al., 2000). This wisdom relies upon the study of system dynamics, which inherently are complex and difficult to predict (Colucci-Gray et al., 2006). Indeed, ***systems thinking skills*** are often described as a core capacity for understanding sustainability (McGinnis & Ostrom, 2014; Meadows, 2009) and a critical skill for the 21st century (National Research Council, 2011). Without such skills social equity goals cannot be addressed effectively. As Mason seeks to align its research and education to promoting equitable solutions for global challenges, systems thinking has never been as important.

Community engagement: An application of systems thinking

Community engagement and civic learning (CECiL, 2023) represents another priority for the university in which systems thinking plays an integral role. The Office of Community Engagement & Civic Learning (CECiL) was formally launched in Spring 2022 as part of Mason’s Quality Enhancement Plan (QEP), which focuses on anti-racist community engagement. Across many fields, communities and stakeholders are increasingly recognized as important partners in building knowledge, and designing and implementing systems (Bosch et al., 2007; Hester et al., 2012; Könnölä & Unruh, 2007). This participatory turn recognizes the limitations of knowledge generated solely within academic institutions.

To examine this issue, workshop speakers Dr. Julie Owen (School of Integrative Studies) and Dr. Jeremy Campbell (Institute for a Sustainable Earth) posed two provocations:

- *What happens when you do community engagement without systems thinking?*
- *What happens when you do systems thinking without community engagement?*

They argued that without systems thinking, community engagement perpetuates stereotypes and relationships of dependency. Without community engagement, systems thinking ignores the social processes by which wicked problems and their solutions are defined (Funtowicz & Ravetz, 1993; Rittel & Webber, 1973). Finally, they maintained that the core principles of systems thinking (Acaroglu, 2023)—plus sustainability—map to those of community engagement (Table 1).

Table 1. Systems thinking principles map to community engagement

Core principles of systems thinking (Acaroglu, 2023)	Community Engagement
Interconnectedness	Dynamic interconnections of communities
Synthesis	Of knowledge and experience
Emergence	Self-organization
Feedback Loops	Info & trust across all community partners
Causality	Multiple vectors of causality; roots vs. symptoms
Systems mapping	Asset mapping; focus on assets/capabilities
Sustainability	Lasting and resilient relationships

Systems thinking in Mason's educational programs

A search on "systems thinking" in the 2022-2023 university catalog reveals two courses, both offered at the graduate level. *EMBA 735: Systems Thinking and Dynamics* is offered by the School of Business and *SYST 514: Systems Thinking* by the Department of Systems Engineering and Operations Research (SEOR). SEOR explicitly addresses systems thinking in confronting complex real-world problems across a variety of fields, including health care, cybersecurity, the environment, transportation, and finance. The department is developing a systems thinking course at the undergraduate level as well.

Systems in sustainability syllabi

The university offers two undergraduate programs in the environment and sustainability: the Bachelor of Science in Environmental Science and the Bachelor of Arts in Environmental and Sustainability Studies. Both describe systems dynamics as at the core of their Student Learning Outcomes (SLOs), but in slightly different ways. The programs state that students should be able to:

- **Environmental Science (BS):** Demonstrate a broad and coherent knowledge of the complexity of environments at various scales, interdependencies between human societies and environments, and key environmental and sustainability challenges and their drivers.
- **Environmental and Sustainability Studies (BA):** Identify the components and interactions that make up the ecosystem, and how this system responds to natural and human interactions.

In order to evaluate how systems are addressed in these programs, graduate student Meaghan Caruso conducted a textual analysis of syllabi from required and optional courses (Appendix B). She accessed 95 syllabi from eight departments for the analysis, representing 49% of courses in these programs. A subset of 31 syllabi (33%) were found to include reference to “system(s).” A further analysis of words frequently co-occurring with the term indicated that students are most commonly exposed to systems concepts through learning about global food systems. Other common co-occurrences with “system(s)” included hydrologic, global, sustainable/sustainability, energy, weather, and farms. From the syllabi, however, it was not possible to determine whether instructors establish learning outcomes for, or actually teach *systems thinking*, as defined above.

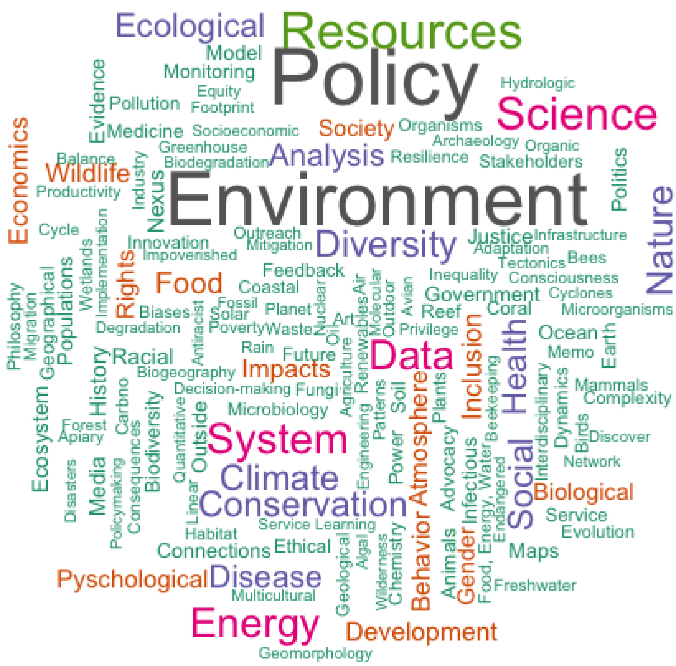

Figure 1. Most frequently occurring terms in Mason environmental syllabi. “System(s)” appears in almost one-third of them.

Teaching systems and systems thinking

In order to better understand how Mason’s instructors address systems and systems thinking in their courses, we sent a pre-workshop online survey to all who registered and to all faculty/graduate students teaching core Environmental and Sustainability Studies (BA) courses, which often cross both of the undergraduate programs mentioned above. While not exhaustive of all courses offered at the university, the 32 respondents included instructors from the School of Integrative Studies (13); Dept. of Environmental Science & Policy (14); Atmospheric, Oceanic & Earth Sciences; Geography and Geoinformation Science; Nutrition & Food Studies; Smithsonian-Mason School of Conservation; and Sport, Recreation and Tourism Management.

While all of the instructors said they address systems in their courses, many were unsure what it means to teach *systems thinking*. And the types of systems—and the way they are taught—differ enormously, as demonstrated in the learning objective examples below.

> **Physical and ecological systems:** Learn the hydrological cycle, carbon cycle, nitrogen cycle, phosphorus cycle, food webs and food chains.
>
> **Social systems:** Explore how social problems can be addressed through cross-sector collaboration among government, for profit, and nonprofit organizations.
>
> **Socio-ecological systems:** Identify important links in the commodity chain from extraction and production to distribution and disposal; analyze how these processes connect distant people and places around the world, from working conditions and environmental impacts to inequalities in consumption and waste.

Respondents said that teaching systems can be difficult because it requires a holistic approach that is unusual within an academic culture that prioritizes silos and narrow specialization. Students struggle in seeing their own experiences in the light of the function of broad and varied systems. And the more expansively that problems are defined, the more overwhelming they can feel. In the workshop, participants further described these barriers and described them as falling into three categories: complexity, affect, and experience (Box 1).

Box 1. Difficulties in teaching systems thinking

Complexity

- Linear thinking
- Disciplinary silos/crossing them
- Different types of data
- People/social systems
- Moving beyond individuals

Affect

- Overwhelmed by scale/scope of problems and systems (*how possibly to intervene?*)
- Overcoming disempowerment and hopelessness (e.g., *climate pessimism*)

Experience and Expectation

- Lack of previous exposure to systems thinking
- Doing well in silos (*staying "safe"*)
- Sticking to the tools you know

Centering change in classroom activities

At the workshop, participants said that overcoming these challenges in teaching systems can be achieved by centering learning around change: analyzing dynamisms, incompleteness, and contingency. At the higher levels of learning, it can require explicit engagement with a diversity of modeling and tools, but at earlier stages can include a wide range of activities (Table 2). Intervening in systems introduces a moral dimension, too, making ethics a critical component of these types of courses.

Academic cultures themselves present barriers to student learning that should be recognized in course design. The use of different language across disciplines may make it harder for students to recognize similar ideas across courses and scaffold knowledge. This ambiguity is particularly prevalent within and across the STEM fields and presents an important instructional challenge (Yoho, 2020). Thus, sharing and collaborating on teaching materials is particularly important. Further, a wide range of resources exist to help instructors develop systems curricula (Table 3).

Table 2. Classroom activities to teach systems and systems thinking

Field trips	Multimedia	Problem-based case studies
Readings	Quantitative models	Stakeholder analysis/mapping
Life-cycle analysis	Simulations	Student-driven concept maps
Lectures/experts	Games and role play	Debates and discussions
Jigsaw problems and exercises	Community projects and co-production (service)	Policy briefs/analytical position papers

Table 3. Recommended resources

Books	1. Meadows, D. H. (2008). Thinking in systems: A primer. Chelsea Green Publishing. 2. Chase, L., & Grubinger, V. (2014). Food, farms, and community: Exploring food systems (First edition). University of New Hampshire Press. 3. Leonard, A. (2011). The story of stuff: The impact of overconsumption on the planet, our communities, and our health-and how we can make it better (Reprint edition). Free Press. 4. Graeber, D., & Wengrow, D. (2021). The dawn of everything: A new history of humanity (First Edition). Farrar, Straus and Giroux. 5. Mann, C. C. (2006). 1491: New revelations of the Americas before Columbus (1st edition). Vintage. 6. Graeber, D. (2012). Debt: The first 5,000 years (Reprint edition). Melville House.

	7. Meadows, D. (1997). Places to Intervene in a System. Whole Earth, 91(1), 78–84. 8. Capra, F., & Luisi, P. L. (2014). The systems view of life: A unifying vision. Cambridge. 9. Allen, K. E. (2019). Leading from the roots: Nature-inspired leadership lessons for today's world. Morgan James.
Online resources	1. Systems Thinking Resources - The Donella Meadows Project https://donellameadows.org/systems-thinking-resources/ 2. InTeGrate Systems Thinking Resources • https://serc.carleton.edu/integrate/teaching_materials/systems.html • https://serc.carleton.edu/integrate/teaching_materials/syst_thinking/index.html 3. Integrating sustainability into engineering education: https://engineeringforoneplanet.org 4. Liberating Structures Process: https://www.liberatingstructures.com/
Modeling platforms	1. Loopy https://ncase.me/loopy/ 2. Vensim https://vensim.com/ 3. Stella https://www.iseesystems.com/store/products/stella-online.aspx 4. SageModeler https://sagemodeler.concord.org/about/index.html 5. NetLogo https://ccl.northwestern.edu/netlogo/ 6. Mental Modeler https://www.mentalmodeler.com/

Team teaching

The need to holistically address social, natural, and physical components of systems requires rethinking how courses are taught. Rather than having one instructor with a narrow range of expertise lead a course, transdisciplinary team teaching can demonstrate to students how different forms of expertise and knowledge—including that of non-academic communities—can be brought to bear on grand challenges like climate change and racism. Team teaching is one of the ways in which universities are increasingly trying to design interdisciplinary educational experiences (Spelt et al., 2009). The traditional vertical organization of academic departments—and budget lines—makes working across disciplines difficult, but doing so can support new collaborations beyond the classroom. Not only is interdisciplinary education more relevant to the grand challenges of our time, interdisciplinary research is demonstrably more impactful (Okamura, 2019).

Leveraging the university as a “living lab”

Higher education institutions like Mason can serve as “living labs” for sustainability, i.e., small-scale social-ecological systems that address challenges of transportation, waste, energy, water, and food (Purcell et al., 2019). For example, the new Mason Living Labs Initiative at https://ise.gmu.edu/malila/ offers support for conceptualizing–and exploring–the university as a socio-ecological system. These types of projects, such as the President’s Park Greenhouse and Honey Bee Initiative, can provide formal and informal learning experiences.

Recommendations

Mason faculty and staff recognize the importance of systems thinking in education and research to achieve the goals outlined in the university’s strategic direction. But departments and colleges require new tools to be able to achieve the types of inter- and trans-disciplinary collaborations to educate students on how to promote sustainability and tackle global grand challenges. The following recommendations, if implemented, would increase the capacity of the university for interdisciplinary education and collaboration that takes a systems approach.

1. Develop a Stearns Center workshop on teaching systems and systems thinking for faculty, instructors, and graduate students across disciplines and domains of knowledge that introduces common terms and concepts, presents best practices, and addresses an array of learning objectives. The course could be developed as a series of three workshops, which would allow participants to obtain a Level 1 credential in systems thinking pedagogy through the Center.

2. Create a Faculty Learning Community in teaching systems thinking through the Stearns Center.

3. Host online resources on systems thinking education on the Institute for a Sustainable Earth site, including syllabi of courses that address the topic and a list of resources, including those on how to incorporate community engagement.

4. Using Curriculum Improvement Grants as a model, develop an Office of the Provost-funded “Team Teaching Grant” for faculty, instructors, and graduate students to develop and teach courses that stretch across departments, colleges, schools, and community/stakeholder groups. Explicitly incorporate CECiL components in the grant RFP.

5. Develop a general education systems thinking course for the Mason Core quantitative reasoning requirement.

6. Utilize the university's campuses as living labs to promote systems thinking among students, faculty, and staff through real-world demonstrations of systems dynamics.

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APPENDICES

Appendix A. “Incorporating Systems Thinking within Environmental Curricula” workshop attendees

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- Laina Lockett, STEM Education Specialist, Stearns Center
- Frank Manheim, Affiliate Professor and Distinguished Senior Fellow, Schar School of Policy and Government
- Ryan McIntyre, Graduate Student, Environmental Science & Policy, College of Science
- Shima Mohebbi , Assistant Professor, Systems Engineering and Operations Research, College of Engineering and Computing
- Julie Owen, Associate Professor, School of Integrative Studies, College of Humanities and Social Sciences
- Esther Peters, Professor, Environmental Science & Policy, College of Science
- Vivek Prasad, Faculty, Environmental Science & Policy, College of Science
- Dale S. Rothman, Associate Professor, Department of Computational & Data Sciences, College of Science
- Laura Sauls, Assistant Professor, Global Affairs, College of Humanities and Social Sciences
- Mara Schoeny, Associate Professor, Jimmy and Rosalynn Carter School for Peace and Conflict Resolution
- John Shortle, Professor and Chair, Systems Engineering and Operations Research, College of Engineering and Computing
- Cindy Smith, Associate Professor, Environmental Science & Policy, College of Science; Director of K-12 Education and Outreach, PEREC
- Sharon Spradling, Program Coordinator, Environmental & Sustainability Studies, School of Integrative Studies, College of Humanities and Social Sciences
- Gregory Unruh, Associate Professor, School of Integrative Studies, College of Humanities and Social Sciences
- Moe Ahmed, Operations Manager, Center for Climate Change Communication
- Fiorella Briceño, Faculty, School of Integrative Studies, College of Humanities and Social Sciences

- Nikita Lad, Doctoral Candidate, Environmental Science & Policy, College of Science
- Stephanie Lessard-Pilon, Associate Professor, Smithsonian-Mason School of Conservation
- Ben Manski , Assistant Professor, Sociology and Anthropology, , College of Humanities and Social Sciences
- James Taft, Faculty, School of Integrative Studies, College of Humanities and Social Sciences
- Judit Ungvari, Research and Innovation Officer, Institute for a Sustainable Earth
- Rachel Yoho, Anti-Racist and Inclusive Teaching Specialist, Stearns Center

Appendix B. Systems Thinking in Environmental Curricula at George Mason University: *A Textual Analysis of Course Syllabi*

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Department of Environmental Science & Policy

Summary
A textual analysis was performed on syllabi from required and optional courses for the Bachelor of Science in Environmental Science and the Bachelor of Arts in Environmental and Sustainability Studies. Ninety-five syllabi from eight departments were analyzed, representing 49% of courses in these programs. The goal of this analysis was to determine if, and in what context, students are exposed to systems thinking concepts throughout the two programs. An analysis of frequent words indicated that "system" is the fourth most common academic term across all 95 syllabi **(Figure 1)**, but further contextual analysis indicated that most of its usage does not refer to systems as addressed in the curricula, but rather procedural systems relevant to the course and/or university. After examining the context of each mention of "system," a subset of 31 syllabi (33%) were found to include reference to systems concepts **(Figure 2)**. A further analysis of words frequently co-occurring with "system(s)" indicate that students are most commonly exposed to systems concepts through learning about global food systems **(Figure 3)**. Other common co-occurrences with "system(s)" included hydrologic, global, sustainable/sustainability, energy, weather, and farms.

Figure 1. Most common academic terms by frequency of syllabi

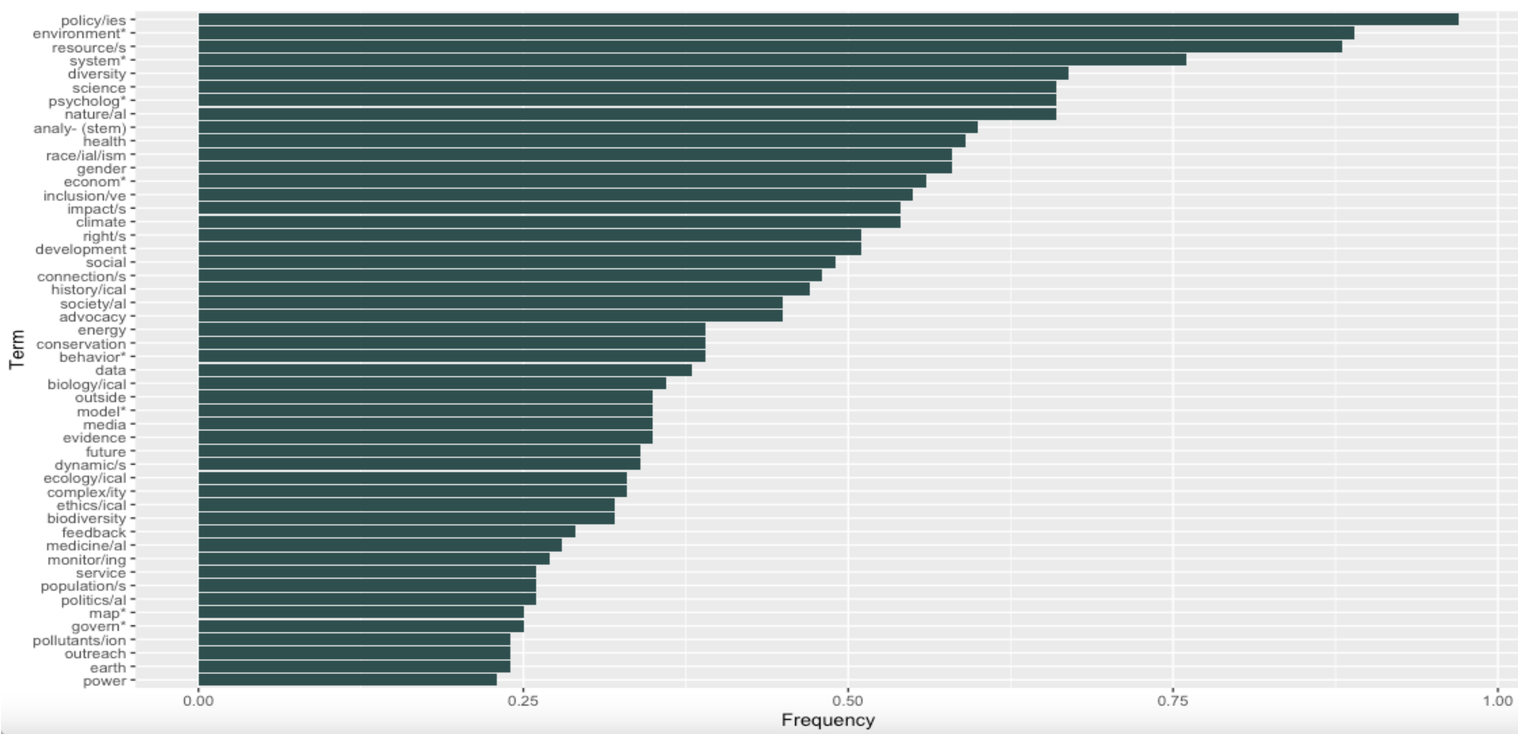
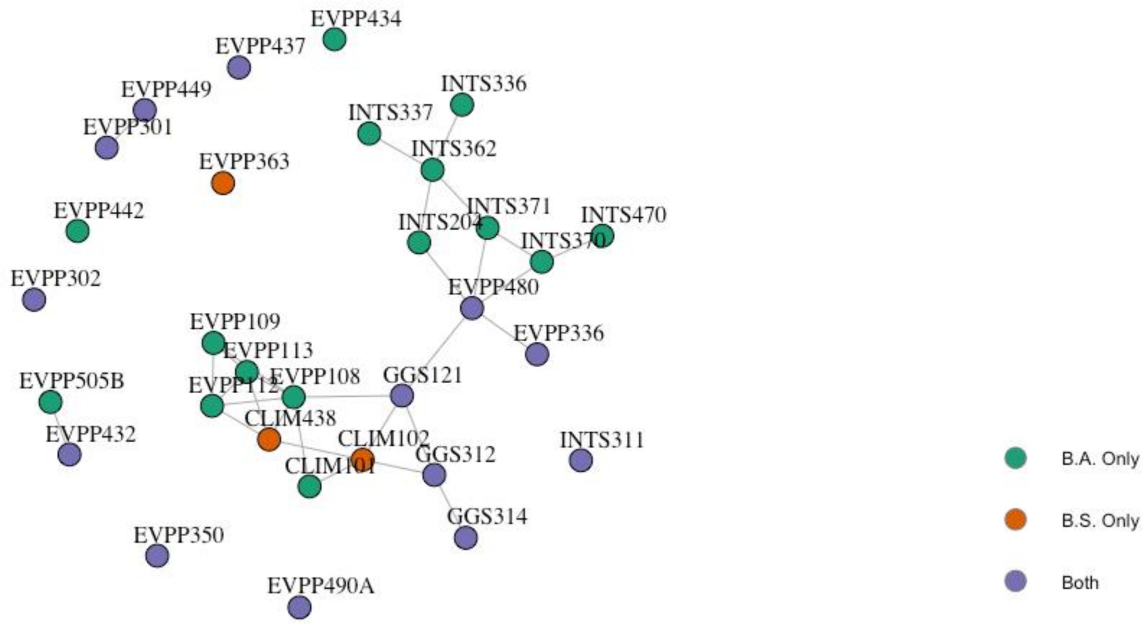


Figure 2. Network graph of 31 syllabi containing systems concepts, associated by frequent academic terms. **Note: see Table 3 below for list of course names*



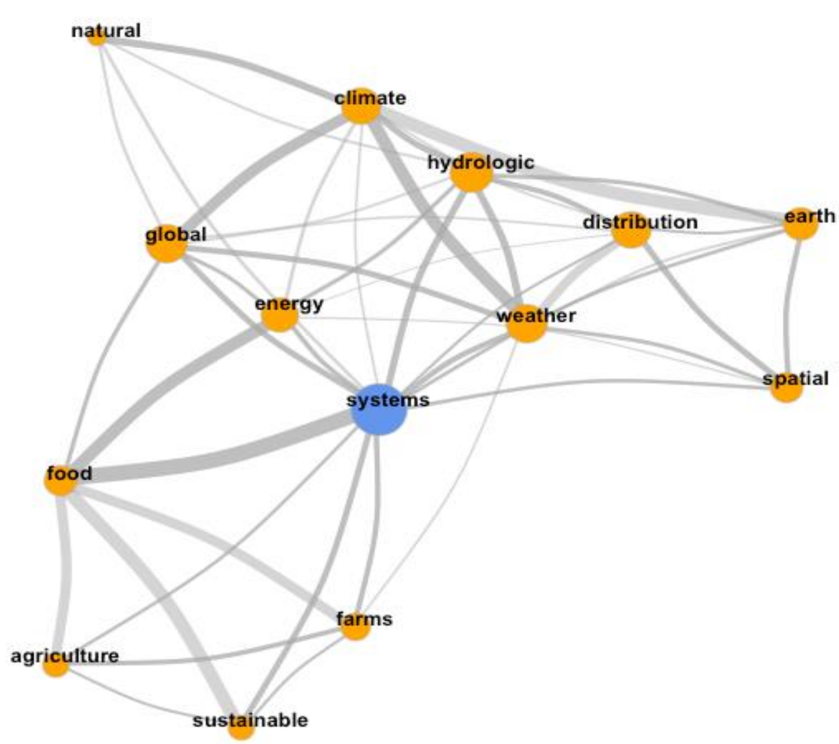


Figure 3. Network graph of most strongly correlated co-occurrences with the term "system(s)"

Purpose
In considering the status of systems thinking pedagogy in environmental curricula at George Mason, a survey of the current programs of study was a necessary first step. This analysis was designed to investigate whether undergraduate students majoring in the two environmental programs (BS and BA) are exposed to systems concepts and if so, in which classes and contexts.

Data Collection
Ninety-five syllabi from courses across these two programs of study were analyzed. These syllabi were obtained through downloading from a department's website, if available, or by email directly from a department representative or professor. When a syllabus for the current academic year was not available, the most recent syllabus available was used in the data set. The required and optional courses for the Environmental Science and Environmental and Sustainability Studies majors were taken from the program websites. See **Table 1** for a breakdown of syllabi by program.

Table 1. Number of syllabi included in analysis listed by academic program

	Total Required and Optional Courses	Number of Syllabi Downloaded	Percentage of Syllabi Accessed
Bachelor of Science (ESP)	59	21	35.59%
Bachelor of Arts (ESS)	90	35	38.89%
Included in both programs	44	34	77.27%

The largest number of syllabi collected came from the Environmental Science and Policy department, but other represented departments include Computational and Data Sciences, Climate Dynamics, Geology, Geography and Geoinformation Science, Integrative Studies, Math, and Parks, Recreation and Leisure Studies. See **Table 2** for a breakdown of syllabi by department.

Table 2. Breakdown of courses represented in dataset, listed by department

Department	Number of Courses included in Programs	Number of syllabi accessed	Percentage	Courses Represented
ANTH	4	0	0	
BIOL	25	0	0	
CDS	1	1	100%	130
CHEM	4	0	0	
CLIM	10	6	60%	101, 102, 112, 412, 438, 456
COMM	1	0	0	
CONF	2	0	0	
ECON	11	0	0	
EVPP	52	44	85%	108, 109, 112, 113, 210, 301, 302, 305, 306, 309, 318, 322, 336, 337A, 337B, 337C, 338, 350, 361, 362, 363, 377, 378, 408, 419, 421, 423, 427, 430, 432, 434, 436, 437, 442, 445, 449, 460, 475, 480, 490A, 490B, 490C, 505A, 505B
GCH	3	0	0	
GEOL	8	4	50%	102, 104, 305, 420
GGS	13	12	92%	121, 302, 303, 304, 305, 306, 307, 309, 312, 314, 321, 354
GOVT	11	0	0	
INTS	24	23	100%	204, 210, 211, 301, 311, 331, 336, 337, 362, 370, 371, 375, 390, 398, 401, 402, 403, 450, 470, 475A, 475B, 490, 498
MATH	3	3	100%	111, 113, 114
MBUS	4	0	0	
MGMT	1	0	0	
NUTR	6	0	0	
PHIL	3	0	0	
PRLS	2	2	100%	300, 402
SOCI	3	0	0	
STAT	1	0	0	
USST	1	0	0	
Total	193	95		

Analysis and Results

After the 95 syllabi were collected as pdf files, the documents were mined using the tm package in RStudio. The most frequent words were found across the entire corpus and parsed for academically relevant terms (see **Figure 4**). The most frequent academic terms were then turned into an incidence matrix by syllabus and plotted, with frequency representing the percentage of syllabus across the corpus that include that term (see **Figure 1** above).

Figure 4. Word cloud of most frequent academic terms across all syllabi

Because of the variation in use of the term "system," it was important to inspect each syllabus for evidence of "system" in the academic sense. Two examples of the use of system in a non-academic context were "COVID health check system" and "grading system." Once each syllabus was inspected, 31 syllabi were identified as including the term "system" as an academic concept. A network graph, color-coded by program, was created to display the relationships between those syllabi and is shown in **Figure 2** above. The relationships displayed are based on the number of academic terms in common between the two syllabi and only those relationships found to be statistically significant ($p < 0.05$) are shown. **Table 3** below lists these courses that address "systems."

Table 3. List of courses that address systems concepts

Course Number	Course Name	Program
CLIM 102	Introduction to Global Climate Change Science	BA only
CLIM 112	Introduction to the Fundamentals of Atmospheric Science (Lab)	BS only
CLIM 438	Atmospheric Chemistry	BS only
EVPP 108	Ecosphere – Introduction to Environmental Science 1 (Lecture)	BA only
EVPP 109	Ecosphere – Introduction to Environmental Science 1 (Lab)	BA only
EVPP 112	Ecosphere – Introduction to Environmental Science 11 (Lecture)	BA only
EVPP 113	Ecosphere – Introduction to Environmental Science 11 (Lab)	BA only
EVPP 301	Environmental Science: Biological Diversity and Ecosystems	Both BS and BA
EVPP 302	Environmental Science: Biomes and Human Dimensions	Both BS and BA
EVPP 336	Human Dimensions of the Environment	Both BS and BA
EVPP 350	Freshwater Ecosystems	Both BS and BA
EVPP 363	Coastal Morphology and Processes	BS only
EVPP 432	Energy Policy	Both BS and BA
EVPP 434	Food-Energy-Water-Nexus	BA only
EVPP/BIOL 437	Ornithology	Both BS and BA
EVPP 442	Urban Ecosystems and Processes	BA only
EVPP 449	Marine Ecology	Both BS and BA
EVPP 480	Sustainability in Action	Both BS and BA
EVPP 490	Special Topics in Environmental Science and Policy: *Coral Reef Health, Ecology, and Conservation*	Both BS and BA
EVPP 505	Selected Topics in Environmental Science: *Energy Law*	BA only
GGS 121	Dynamic Atmosphere and Hydrosphere	Both BS and BA
GGS 307	Geographic Approaches for Sustainable Development	BA Only
GGS 312	Physical Climatology	Both BS and BA
GGS 314	Severe and Extreme Weather	Both BS and BA
INTS 204	Leadership Theory and Practice	BA only
INTS 311	The Mysteries of Migration: Consequences for Conservation	Both BS and BA
INTS 336	Poverty, Wealth, and Inequality in the US	BA only
INTS 337	Social Justice Consciousness and Action	BA only

Course Number	Course Name	Program
INTS 362	Social Justice and Human Rights	BA only
INTS 370	Sustainable Food Systems	BA only
INTS 371	Food Systems and Policy	BA only
INTS 470	Professional Pathways in Sustainable Food Systems	BA only

Finally, a word co-occurrence analysis was run on the 31 syllabi to see which words were most strongly associated with "systems" in these classes. The goal of this analysis was to discover the most common contexts in which students are encountering systems concepts throughout the BA and BS programs. The outcome of this co-occurrence analysis is shown in the network graph above (**Figure 3**). The most highly-correlated term with "systems" was food, demonstrating that students are frequently exposed to systems concepts through learning about food systems. Other common co-occurrences were "energy," "climate," weather," and "hydrologic."

Conclusion

A textual analysis of course syllabi cannot provide a comprehensive view of specific teaching practices and systems thinking pedagogy present in the Environmental Science and Environmental and Sustainability Studies majors at George Mason. However, this analysis does highlight various curricula throughout both programs of study where students are encountering systems concepts and provides a launching point for further conversation regarding the importance and best practices of applying a systems thinking lens to our global social-ecological systems.