

## A Student-Driven Assessment of an Undergraduate Biology Curriculum Using an Ecosystem Health Competency Framework

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**Abstract:** Gen-Z students care deeply about sustainability in the face of anthropogenic climate change, and many undergraduates at college want to gather the knowledge, skills, and motivation to create a more sustainable future. Therefore, educational institutions must equip students with the tools to practice and enact sustainability. However, it is unclear if sustainability education provides students with the necessary competencies to enact change. Here, we employ a novel student-led approach to assess a department's curriculum through a multi-domain Ecosystem Health Competency Framework (EHCF) lens to identify gaps in the curriculum that can be filled by making domain-based recommendations. Also, we analyzed the efficacy of undergraduates as curriculum assessors to determine the applicability of this model to future contexts. Overall, we identified multiple domain-based gaps across the Biology Department's curriculum, including for Diversity, Equity, Inclusion, and Justice in Ecosystem Health (Domain 2), Values, Morals, and Ethics (Domain 9), and others. Based on the identified gaps, we suggested potential courses to ensure that the Biology Department covers all EHCF domains across the entire curriculum. Based on the success at identifying EHCF domain-based gaps, generation of course recommendations, and the receptiveness and enthusiasm of faculty, we believe this unique approach to curriculum assessment can be a widely applicable model for future curriculum assessments.

**Keywords:** Sustainability, Biology, Assessment, Undergraduate Curricula, Student-led, Ecosystem Health

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## **Introduction**

As Generation Z students, we are increasingly concerned with global challenges related to climate change, biodiversity loss, water and air quality, and environmental justice. Many college students are interested in acquiring the knowledge and skills to address these challenges. With all of these challenges, many undergraduate students have feelings of climate anxiety; in fact, an international poll conducted by Amnesty International of more than (n=10,000) Gen Z respondents found that 41% of respondents saw climate change as the most pressing issue facing the future of the world (Barbiroglio, 2019). Climate anxiety can manifest in feelings such as ecoparalysis (Albrecht, 2011) and also as ‘practical anxiety’ (Kurth, 2018), which can drive motivation for both individual and collective climate action (Pihkala, 2020). With this in mind, sustainability education must communicate the existential threats of the climate crisis without driving people into a sense of paralysis. Consequently, it is incumbent upon higher education institutions to provide curricula that not only teach students knowledge and skills surrounding sustainability but also motivate students to enact change in the face of climate anxiety.

However, sustainability education does not fit neatly within the frequently siloed curricula of many traditional academic departments. Many institutions have modified traditional curricula and created new curricula to help meet the needs and interests of those students focused on sustainability. However, it is not clear if these programs are providing the necessary toolkit for students to enact change. Sustainability is an aspect of all subjects of study and should be incorporated in a way that teaches students that it is omnipresent, and not a separate process to learn. To that end, we undertook a student-driven evaluation of the Department of Biology’s curriculum at the University of Minnesota Duluth (UMD), considering a newly created set of ecosystem health competency standards.

In 2022-2023 the University of Minnesota Ecosystem Health (ESH) Working Group of the University of Minnesota’s Institute on the Environment (IonE) created an ecosystem health competency framework (EHCF) for undergraduate educators (Colombo et al., 2023) to analyze and adapt curricula to emphasize the “animal-human-environment health interface”. The EHCF is a set of 9 interdependent domains designed to support the development and alignment of undergraduate courses and curricula with ESH goals. Within each of these domains is a set of competencies that provide more specific explanation and guidance. Also, the purpose of the ESH framework is for instructors to tailor their curriculum to their specific course, class level, and teaching method while integrating EHCF principles; it is not intended to be a specific checklist. Every competency within each domain is not expected to be covered in a course. Rather, the framework is designed to encourage a student’s mastery in these domains as they complete their undergraduate education. The 9 domains are listed in Table 1 below.

**Table 1.** Ecosystem health competency framework (EHCF) domains.

| <b>Domain</b> | <b>Description</b>                                              |
|---------------|-----------------------------------------------------------------|
| 1             | Characterizing Health at the Animal-Human-Environment Interface |
| 2             | Diversity, Equity, Inclusion, and Justice in Ecosystem Health   |
| 3             | Systems Thinking                                                |
| 4             | Communication                                                   |
| 5             | Integrative Leadership                                          |
| 6             | ESH Project Management                                          |
| 7             | Modes of Inquiry                                                |
| 8             | Knowledge to Impact                                             |
| 9             | Values, Morals, and Ethics                                      |

We determined the EHCF as a comprehensive framework designed to help prepare students for ESH competency. While there are many sustainability curricula in existence, this is the first cross-curricular framework, so we selected it as the metric by which we would evaluate our curriculum. It is important to note, however, that this framework had not been published prior to these courses being taught. Consequently, faculty could not have been aware of them. This evaluation was conducted as a mechanism to consider future improvements to the curriculum.

The University of Minnesota Duluth (UMD) is a mid-sized regional university in the midwestern United States. In Fall 2022, 9675 students were enrolled at UMD, 7754 of which were undergraduate degree-seeking. The Department of Biology is one of the largest academic departments at UMD with 554 undergraduate majors enrolled in Fall 2022. Additionally, students from many other departments on campus enroll in courses through the Department of Biology, including Chemistry and Biochemistry, Earth and Environmental Sciences, Applied Human Sciences, and Education. The Department offers both Bachelor of Arts and Bachelor of Sciences undergraduate degrees. The Bachelor of Sciences degree is split into two tracks: Genetics, Cell, and Development, and Environment, Evolution, and Behavior (EEB). Since the majority of the students focused on environmental and sustainability issues are in the EEB track, we chose to focus our evaluation on this degree plan.

Rather than asking Biology faculty to map their courses and curricula to the EHCF, we decided to enlist a team of students to do so. This approach has the advantage of determining how our students view the curriculum in this light. Further, we are hopeful that it will remove instructor bias, revealing what our courses and curriculum actually do, from the students' perspective, rather than what the faculty intends for it to do. The use of students to map undergraduate programs has not been widely reported. One such project asked students to map a first-year

linear algebra course at the University of Toronto (Romkey and Bradbury, 2007). The authors noted that the results of this project served as a useful tool in curriculum development, although there were some challenges in the students' ability to understand learning objectives presented by the course instructors. To address this challenge, our students received training in mapping to the EHCF, as well as faculty support throughout the project. Following training, students evaluated the B.S. Biology- EEB track curriculum during the Spring 2022 term. Following their evaluation, they presented their findings to the UMD Department of Biology faculty.

This project had 5 primary goals:

1. Evaluate UMD's Biology curriculum using "An Ecosystem Health Competency Framework for Undergraduate Education" and identify areas that the curriculum addresses well and those that could/should be better addressed.
2. Provide feedback to instructors of individual courses on how well their courses meet the Ecosystem Health Competency Framework and potential course modifications that could allow them to better meet these standards.
3. Guide undergraduate students interested in an education rich in Ecosystem Health Preparedness at UMD on programs and courses well suited to their interests.
4. Determine the effectiveness of using undergraduate students to review an academic curriculum.
5. Provide a possible unique model for other schools to use for curriculum assessment.

Here we present our review of a curriculum program by undergraduate students using a set of ecosystem health education standards, as well as our findings of this review. We found our approach useful for identifying strengths and potential areas for improvement that would help our students develop the knowledge and skills needed to effect change in the areas of ecosystem health and sustainability. We present our findings here because we found this process to be beneficial to both students and faculty of the Department of Biology. Further, using undergraduate students to evaluate departmental curricula could be a tool that is more widely utilized and help provide departments and instructors with useful course and curricular feedback.

This study was developed as a preliminary step to create departmental changes in science curricula that integrate and prioritize sustainability-teaching based on a student-driven model. This research also offers a novel model for other higher education institutions (HEIs) to utilize for sustainability curriculum assessment.

## **Methods**

We used criteria stated in the Ecosystem Health Core Competency Domains to evaluate the courses offered by the Biology Department at UMD. The biology program at UMD offers both a Bachelor of Science (B.S.) and a Bachelor of Arts (B.A.) degree. At the time of this study, The

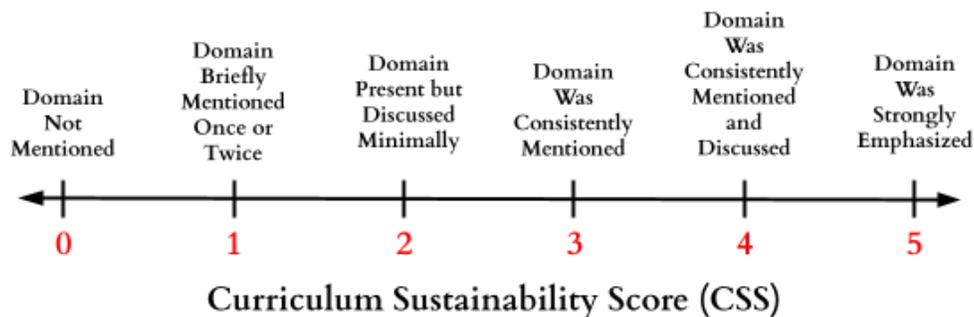
B.S. offered two tracks: 1) Ecology, Evolution, and Behavior (EEB) and 2) Cell, Genetics, and Development (CGD), and the B.A. offered two tracks: 1) Human Biology BA and 2) Life Sciences. To address the goals of this study, we focused on courses that could be taken by students in the B.S.-EEB major. Courses were divided into three broad categories: Core Courses, Biology Electives, and Courses from Other Programs. Because of their large number, we did not evaluate courses in our university's Liberal Education Program.

Briefly, we will define the different domains (Colombo et al., 2023):

- Domain 1 (Characterizing Health at the Animal-Human-Environment Interface) focuses on the interconnections among human health, ecosystems, and the environment around us, and how human actions are changing these relationships.
- Domain 2 (Diversity, Equity, Inclusion, and Justice in Ecosystem Health) emphasizes how Diversity, Equity, Inclusion, and Justice (DEIJ) are critical in a holistic definition of sustainability. For instance, topics such as environmental racism, Indigenous practices, race as a social construct, implicit bias, and global approaches to sustainability are all present within this domain.
- Domain 3 (Systems Thinking) was designed to understand how different human and natural systems interact with each other across disciplines. We primarily focused on course content including inclusive teaching about system levels such as cellular, individual, community, ecosystem, etc.
- Domain 4 (Communication) highlights ways in which students can become more effective communicators. Examples include effective presentation skills, cross-cultural communication, scientific writing, and knowing one's audience.
- Domain 5 (Integrative Leadership) tackles how one can be self-driven, collaborate with groups, and facilitate collaboration between/among different groups or stakeholders.
- Domain 6 (ESH Project Management) centers on having a curriculum that prepares students to create and manage projects that affect change, including research and emergency response. Management and timeline skills are emphasized in this domain.
- Domain 7 (Modes of Inquiry) emphasizes student understanding of the process of generating scientific questions, creating hypotheses, and researching a topic effectively. It focuses on giving students the tools to address scientific questions, such as interpretation of primary literature, data analysis, and experimental design.
- Domain 8 (Knowledge to Impact) focuses on transforming classroom knowledge into tangible impact outside the classroom. There are numerous mechanisms to make this translation, such as encouraging students to perform original research on the topic, measure outcomes, engage with the community, and envision how they would respond to different management scenarios.
- Domain 9 (Values, Morals, and Ethics) emphasizes how ethics and morals are needed in conversations surrounding sustainability. Curricula should emphasize a variety of ethical and moral viewpoints, include diverse problem-solving mechanisms, and ask students to critically think about their values when approaching their respective fields.

We evaluated each course for the presence and level of incorporation of each of the 9 ecosystem health competency framework domains (Table 1) into its curricula. We ranked the degree to

which each domain was a part of the course on a scale from 0 to 5 using the rating scale below (Figure 1).



**Figure 1.** Curriculum Sustainability Score (CSS) used to assess each course for each of the (n=9) Ecosystem Health Core Competency Domains.

To evaluate the domains within each class, we assessed a variety of course materials. To begin, we read through the syllabus of each course to note the course objectives and overview of learning expectations. We then looked through the provided materials on the Canvas learning management system to identify any specific examples of each domain and understand how the domain was integrated into the course. Finally, we looked through discussion topics, assignments, lab protocols, and assessments for any additional mentions of each domain.

For each core course, two students who took the course before analyzed the curriculum for each domain's score on the CSS, and compared scores for each domain to ensure methodological consistency. Due to the relatively large number of Biology Electives and Courses from Other Programs, only one student evaluated each course. For courses that none of the team evaluators had taken, evaluations were based on course materials provided by the instructors and on interviews with one or more students who had taken that course. In this interview, evaluators explained each domain, looked through course materials with the student, gave examples of scores for other courses for that domain, and asked how many times and when that domain was a prominent course topic.

Following the course evaluation, the entire team discussed all of the rankings as a group to look for consensus. The student team suggested ways for the courses that were identified as deficient in one or more categories might be modified. Finally, the student team suggested additional courses that could be added to the biology major so that it could fulfill all nine domains at a high level. These results and suggestions were shared with the Department of Biology faculty at a departmental meeting for feedback.

## Results

For each domain, we have presented a summary of the results. We have also included select specific comments that illustrate documentation that the evaluators made for how courses addressed each domain and potential areas of improvement. For core courses taught by the same

instructor, agreement between both reviewers' scores was highly consistent and always within 1 point on the CSS scale.

**Table 2.** Curriculum Sustainability Scores (CSS) for courses in the Biology curriculum for the 9 ESH domains. Scores are on a 0-5 scale (0 = domain not mentioned, 5 = domain was strongly emphasized; see Figure 1). Core courses had 2 reviewers and CSS were averaged. Biology Electives and Courses from other programs each had one reviewer.

|                                                   | Domain 1         | Domain 2                               | Domain 3         | Domain 4      | Domain 5               | Domain 6               | Domain 7 | Domain 8            | Domain 9        |
|---------------------------------------------------|------------------|----------------------------------------|------------------|---------------|------------------------|------------------------|----------|---------------------|-----------------|
|                                                   | Ecosystem Health | Diversity, Equity, Inclusion & Justice | Systems Thinking | Communication | Integrative Leadership | ESH Project Management | Inquiry  | Knowledge to Impact | Values & Ethics |
| <b>Core Courses</b>                               |                  |                                        |                  |               |                        |                        |          |                     |                 |
| Biol 1011- General Biology I                      | 0.5              | 0.5                                    | 3                | 3.5           | 0                      | 0                      | 4        | 1                   | 1               |
| Biol 1012- General Biology II                     | 3.5              | 1                                      | 3.5              | 5             | 3                      | 0.5                    | 4        | 1                   | 1.5             |
| Biol 2201- Genetics                               | 0.5              | 4                                      | 2                | 0             | 1                      | 0                      | 0.5      | 2                   | 1.5             |
| Biol 2801- General Ecology                        | 4.5              | 0.5                                    | 4.5              | 0             | 0                      | 2                      | 0.5      | 2                   | 0               |
| Biol 2802- Ecology Lab                            | 3.5              | 0                                      | 3                | 5             | 4                      | 0                      | 5        | 1.5                 | 2               |
| Biol 3100- Cell Biology                           | 2.5              | 0                                      | 1.5              | 0.5           | 0                      | 0                      | 0        | 0                   | 0               |
| Biol 3401- Evolution                              | 1.5              | 1                                      | 1                | 1             | 0                      | 0                      | 0.5      | 0                   | 0               |
| Biol 3987- Communication in Biology               | 0                | 1                                      | 5                | 5             | 0.5                    | 1.5                    | 4        | 0.5                 | 0.5             |
| <b>Biology Electives</b>                          |                  |                                        |                  |               |                        |                        |          |                     |                 |
| Biol 3502- General Microbiology                   | 4                | 0                                      | 4                | 1             | 1                      | 0                      | 0        | 1                   | 2               |
| Biol 3512- Biology of HIV and AIDS                | 4                | 0                                      | 5                | 3.5           | 0                      | 0                      | 2        | 4                   | 3               |
| Biol 3601- Plant Diversity                        | 3                | 2                                      | 0                | 2             | 0                      | 0                      | 0        | 0                   | 0               |
| Biol 3701- Animal Diversity                       | 3                | 0                                      | 2                | 1             | 1                      | 0                      | 0        | 0                   | 0               |
| Biol 3760- Marine Biology                         | 0                | 0                                      | 2                | 0             | 0                      | 0                      | 0        | 0                   | 0               |
| Biol 3763- The Biology of Gender                  | 2                | 0                                      | 2                | 4             | 2                      | 0                      | 2        | 1                   | 1               |
| Biol 3772- Human Physiology                       | 2                | 0                                      | 4                | 3             | 2                      | 0                      | 3        | 0                   | 1               |
| Biol 3835- Freshwater Ecology                     | 5                | 2                                      | 4                | 1             | 1                      | 1                      | 1        | 0                   | 1               |
| Biol 4231- Molecular Biology                      | 3                | 0                                      | 2                | 5             | 0                      | 4                      | 2        | 3                   | 2               |
| Biol 4232- Molecular Biology Laboratory           | 3                | 0                                      | 0                | 2             | 1                      | 4                      | 4        | 3                   | 1               |
| Biol 4301- Plant Growth & Development             | 4                | 0                                      | 4                | 5             | 4                      | 0                      | 4        | 2                   | 1               |
| Biol 4361- Developmental Biology                  | 3                | 0                                      | 2                | 4             | 4                      | 5                      | 4        | 4                   | 3               |
| Biol 4402- Trees of Life: Assembly & Applications | 0                | 0                                      | 3                | 5             | 3                      | 2                      | 5        | 0                   | 1               |
| Biol 4511- Medical Microbiology                   | 2                | 0                                      | 5                | 4             | 0                      | 4                      | 0        | 4                   | 2               |
| Biol 4604- Plant Physiology                       | 3                | 0                                      | 4                | 4             | 5                      | 5                      | 5        | 4                   | 1               |
| Biol 4761- Ichthyology                            | 3                | 1                                      | 4                | 1             | 0                      | 1                      | 1        | 2                   | 1               |
| Biol 4763- Ornithology                            | 2                | 0                                      | 3                | 2             | 0                      | 0                      | 2        | 0                   | 0               |
| Biol 4764- Mammalogy                              | 3                | 0                                      | 4                | 2             | 3                      | 0                      | 3        | 3                   | 3               |
| Biol 4804- Methods in Forest Ecology              | 4                | 0                                      | 5                | 5             | 4                      | 5                      | 3        | 4                   | 1               |
| Biol 4861- Lake Ecology                           | 3                | 0                                      | 4                | 1             | 4                      | 0                      | 0        | 3                   | 0               |
| Biol 4891- Animal Behavior                        | 4                | 0                                      | 5                | 5             | 0                      | 0                      | 5        | 4                   | 1               |
| Biol 4992- Classic Readings in Natural History    | 4                | 0                                      | 5                | 5             | 0                      | 0                      | 5        | 4                   | 1               |
| Biol 5809- Ecological Statistics                  | 2                | 0                                      | 4                | 1             | 1                      | 1                      | 5        | 1                   | 1               |
| Biol 5865- Conservation Biology                   | 4                | 0                                      | 4                | 4             | 0                      | 1                      | 3        | 3                   | 4               |
| <b>Courses from other programs</b>                |                  |                                        |                  |               |                        |                        |          |                     |                 |
| Chem 1153/1154- General Chemistry I (with Lab)    | 1                | 0                                      | 0                | 0             | 0                      | 0                      | 3        | 2                   | 0               |
| Chem 1155/1156- General Chemistry II (with Lab)   | 0                | 0                                      | 1                | 0             | 0                      | 0                      | 0        | 2                   | 0               |
| Chem 2212- Environmental Chemistry                | 5                | 0                                      | 3                | 3             | 4                      | 1                      | 1        | 5                   | 4               |
| Chem 2222/2223- Quantitative Analysis (with Lab)  | 1                | 0                                      | 1                | 1             | 0                      | 0                      | 2        | 0                   | 0               |
| Chem 2541/2543- Organic Chemistry I (with Lab)    | 0                | 0                                      | 0                | 2             | 0                      | 0                      | 3        | 0                   | 0               |
| Chem 2542/2544- Organic Chemistry II (with Lab)   | 0                | 0                                      | 0                | 2             | 0                      | 0                      | 3        | 0                   | 0               |
| CS 1121- Intro to Programming in Visual BASIC     | 0                | 0                                      | 4                | 1             | 0                      | 0                      | 0        | 0                   | 0               |
| Math 1296- Calculus I                             | 0                | 0                                      | 0                | 0             | 0                      | 0                      | 0        | 0                   | 0               |
| Phys 1001- Introduction to Physics I              | 0                | 0                                      | 1                | 0             | 0                      | 0                      | 0        | 1                   | 0               |
| Phys 1002- Introduction to Physics II             | 0                | 0                                      | 0                | 0             | 0                      | 0                      | 0        | 0                   | 0               |
| Stat 2411- Statistical Methods                    | 0                | 0                                      | 0                | 0             | 0                      | 0                      | 0        | 0                   | 0               |
| Writ 3150- Advanced Writing                       | 0                | 0                                      | 0                | 5             | 0                      | 0                      | 0        | 0                   | 0               |

### Domain 1- Characterizing Health at the Animal-Human-Environment Interface

After evaluation of the coursework, the Biology Department appears to have a strong emphasis on the importance of both ecosystem health and human health separately, however, many courses lack a connection between these two concepts. Core classes and some biology electives have course materials and activities that encourage students to focus on the broader biological implications of humans on ecosystems as well as the factors that contribute to healthy ecosystems. Biology electives focused on cell, molecular, and human biology have inherent ties

to the importance of human health and environmental factors that can impact physical well-being. Environmental Chemistry is a course from another program that successfully ties the concepts of ecosystem health and human health together.

Specific comments:

- General Biology II: The class focused on interconnectedness within ecosystems. There could be a larger emphasis on the interplay between human/environmental health. The importance of clean air/water/land was mentioned in lectures throughout the course.
- Genetics: The class discussed topics such as biotechnology and GMO plants and their implications for agriculture/human health. The course emphasized human health but not environmental health or the integration between both.
- General Ecology: The curriculum consistently emphasized human impacts on biodiversity and ecosystem health across a vast majority of the lectures. Students discussed deforestation, mining, climate change, habitat fragmentation, eutrophication, human impacts on natural selection, extinction vulnerability, interconnectedness and food webs, and alterations to nutrient cycling.
- Ecology Lab: This course consistently mentioned ecosystem health and resilience. There was some discussion about invasive species and extinct organisms. There was no mention of impacts on human health.
- Environmental Chemistry: The course included frequent discussions about how anthropogenic processes impact the environment and human health, such as how fossil fuel combustion impacts ocean acidification and aquatic food webs, and how/why legislation for clean water and air arose in the United States. Environmental chemistry is not currently required for the biology major, but we recommend that it becomes a core class to address the importance of environmental issues.

## **Domain 2- Diversity, Equity, Inclusion, and Justice in Ecosystem Health**

The Diversity, Equity, Inclusion, and Justice domain was not emphasized in the biology curriculum. The highest-scoring course was Genetics, which included topics such as race as a social construct, sex versus gender, and awareness of implicit biases. Other core courses such as General Biology I and II, General Ecology, Evolution, and Communication in Biology included topics on race being a social construct, biodiversity having different spiritual/cultural importance, and how different backgrounds have different challenges, though in much less detail and with less frequency. The remaining biology elective courses reviewed seldom mentioned this domain. Within the Biology Department, topics relating to non-western scientific practices and the impact of environmental degradation/policy/on different groups of people and their health should be incorporated into core and elective courses. Recommendations for courses from other departments that could help address this domain include POL 3040, (Women in Politics), POL 3100 (Contemporary Issues in Human Politics), and EES 3444 (Traditional Ecological Systems). The political science coursework would provide background knowledge for students concerning diversity, equity, and inclusion. The earth and environmental science course would add the ecosystem connection to diversity, equity, and inclusion with respect to Indigenous peoples.

Specific comments:

- General Biology I: The very last week touched on human evolution and how race isn't biological. Nothing was related back to the environment.
- General Biology II: The syllabus stated, "understand key ethical and cultural considerations associated with scientific inquiry", however this was not significantly integrated into the course.
- Genetics: This course emphasized how different genetic alterations affect different people, resulting in genetic disorders, physical differences, etc. The curriculum mentioned the importance of sickle cell. Students had a productive discussion of eugenics: how it impacted immigration, interracial marriage legality, women's rights, and the historical and present-day significance.
- Communication in Biology: The course discussed keeping different backgrounds in mind while presenting or evaluating a seminar . The instructor discussed how everyone comes from a different background and faces different challenges.

### **Domain 3- Systems Thinking**

We looked to see if the classes made an effort to teach students how it takes many moving parts to make the whole system and how that system works. Systems Thinking is a strength of the Biology Department, especially in core and biology elective courses. General Biology I had a large component of the human system and how everything must work together to properly function. General Biology II focused on organisms, cells, and ecosystems as systems at different levels. A main emphasis of General Ecology is how systems interact within the ecosphere.

Specific comments:

- General Biology II: Instruction centered around organisms as systems, cells as systems, ecosystems as systems, and the integration of humans within the earth's environmental system. A balance of lectures about human health/physiology and environmental systems were integrated into the course.
- General Ecology: The course objective was to teach about the interactions within the earth's environment. These interactions were explained at the individual level, population level, community level, and ecosystem level, and further expanded on the interaction between land and water. There could be a bit more integration with how humans fit into the system of the environment.
- Mammalogy: The course was always discussed in the context of ecosystems- how mammals interact, including humans.
- Forest Ecology: The course emphasized the importance of looking at forests as a system. The course compared different organizations and their methodologies.
- Human Physiology: An emphasis on systems thinking was present in terms of systems of the human body and how smaller systems come together to create larger ones.

## **Domain 4- Communication**

For the core classes, communication is heavily emphasized in core courses such as General Ecology Lab and General Biology I & II. In particular, for General Biology I & II, the lab sections involve the writing of lab reports. This served as an introduction to scientific writing. Across the curriculum, students are expected to create presentations and learn the process of scientific writing. Since the electives and core courses scored similarly, this implies that these principles are consistently emphasized in the curriculum. Also, we noticed that courses varied in how well the curriculum teaches students to create effective presentations.

Specific comments:

- General Biology II: This course had a strong emphasis on communication in the lab portion of the class, including writing a lab report and doing presentations. The discussion section of this course also encouraged communication between peers.
- Ecology Lab: Proper scientific communication was emphasized in every class. The curriculum heavily emphasized paper writing and displaying results clearly and concisely.
- Communication in Biology: Communicating science to others was the main focus of the course. A strong emphasis was placed on listening and effective communication.
- Forest Ecology: Communication was integrated through a project organized around interviewing a professional researcher/forester. Students designed their own questions to ask their interviewees. The end-of-semester project was also meant to educate community members about the importance of healthy forests.

## **Domain 5- Integrative Leadership**

Courses scoring high in this domain had a strong emphasis on group work and also an individual leadership component, where students either had to 1) design their own experiment, 2) gather information for a specific component within a larger group project, or 3) reflect on their role as a leader within a group project. In courses that best met the criteria of this category, students led their own projects and collaborated to complete lab assignments. In courses such as Lake Ecology and Forest Ecology, students were encouraged to collect a specific piece of data for a larger group project by using sampling equipment in the field.

Overall, we noticed that many courses tend to focus on self leadership, rather than group leadership. Students are required to create individual projects and organize their ideas so they can be presented to a group in many courses. Classes where group projects are a key component would benefit from teaching about *how* successful groups are formed and *how* leadership—including personal leadership—can contribute to a group project.

## **Domain 6- ESH Project Management**

Courses in the Biology Department in which students design and perform their own experiments were the highest scoring in the ESH Project Management domain. These courses encouraged

students to read primary literature and develop research questions from course content. These processes allowed students to gain a better understanding of the way that research is conducted. The courses also placed an emphasis on the discussion of potential next steps or drawbacks of experiments. Methods in Forest Ecology is a course offered that best emphasizes ESH project management by exposing students to a variety of different methods used in the field. This course draws upon a combination of hands-on field techniques as well as presentations and interviews with a wide array of professional researchers to demonstrate different approaches to large-scale projects.

Overall, this is not a domain that is emphasized in the core curriculum due to the introductory nature of these classes. Courses with laboratory sections have the widest opportunity for growth in this area by explaining the process of how real research is conducted and asking students how they might approach different projects. Allowing students to interact with real researchers outside of the University and speak with experts who have managed their own projects also increases competency in this domain by giving students hands-on experience. An additional course that could be used to supplement this category would be EES 4102, Environmental Assessment.

Specific Comments:

- General Ecology: The course had an emphasis on how different experiments/studies can be carried out and why their methodology is important. However, students did not have the opportunity to craft and experiment or manage a project.
- Forest Ecology: All data collected was managed by the students using Excel/Google Sheets and archived for further use. The plots themselves were a major project that required communication between groups.
- Developmental Biology: The students designed every experiment by themselves, worked in groups, and utilized planning/organizational skills.

## **Domain 7- Modes of Inquiry**

The inquiry domain is a strength within the Biology Department. Courses that scored the highest in this domain had an emphasis on hypothesis-driven inquiry, data collection, data analysis, research methods, and reading primary literature. Core courses that scored highly included General Biology I & II, Ecology Lab, and Communication in Biology. Biology electives that scored highly included: Ecological Statistics, Animal Behavior, Trees of Life, and Plant Physiology. Upper-division courses tend to put more emphasis on learning information as compared to performing inquiry-type tasks such as collecting data unless there is a lab component. Since this domain is strongly represented in the Biology Department coursework, recommendations are more focused on the current coursework rather than bringing in courses from other Departments. One recommendation is to start teaching techniques on reading primary literature to students earlier in the core courses such as General Biology I & II.

Specific Comments:

- General Biology I: The lab section especially encouraged inquiry. Based on data gathered in class, students were expected to generate questions and hypotheses, which in turn, become lab reports. Inquiry did not seem to be a part of the lecture curriculum.
- Ecology Lab: Hypothesis development and testing was a central theme of this course. Students were asked to design and develop projects based on their own research using primary literature.
- Animal Behavior: Students were encouraged to think about why a behavior might evolve in specific animals and how to test these hypotheses.
- Trees of Life: Students were required to submit meaningful thoughts and questions in response to assigned literature and dive into articles that may address those questions.

### **Domain 8- Knowledge to Impact**

This domain was not seen as a strength in this curriculum. It was not well addressed in most of the core courses. We found that although many courses included an aspect of knowledge to impact in their syllabi, curricula didn't emphasize why students were learning about it. Most commonly, it was mentioned briefly when discussing potential future careers or research programs. Some emphasis in General Ecology was placed on how and why methodology was important and how it may pave the way for other discoveries. Some of the biology electives, especially those focused on cell, molecular, and human biology, better addressed this domain due to the human health implications.

### **Domain 9- Values and Ethics**

In Evaluating the Values and Ethics domain, we focused on determining whether or not the curriculum emphasized ethical and moral questions surrounding different topics, such as genetic engineering, climate, plagiarism, and ethics of ecosystem management. We also assessed whether students were asked to consider ethical and value questions. We determined that the curriculum addressed this domain in the context of genetic engineering, gene therapy, and genetically modified organisms (GMOs) for the core classes. Additionally, the ethics of plagiarism were occasionally mentioned. In the elective courses, the curriculum focused on ethical issues such as public health, plagiarism, and the management of disease. Topics regarding the ethics of the sustainable management of ecosystems were discussed in only a few courses, notably BIOL 5865: Conservation Biology.

### **Overall Evaluation and Recommendations**

After thoroughly analyzing each course, members of the evaluation team attended a Biology Department Faculty Meeting to present our methodology and findings to the instructors who would benefit from our results. Overall, faculty members agreed that their courses lacked content in sustainability and DEIJ (Domain 2). However, many were enthusiastic that we had taken the time to analyze their courses and were receptive to our feedback. Looking into the future, we will use the input gathered from our evaluation team to meet with faculty members one-on-one to discuss how aspects of their course curricula could be modified. As courses change and students

move through the biology degree, it will be crucial to maintain the evaluation process and hold instructors accountable for the intersectional content of their courses. To ensure this, we propose adding a similar evaluation of each domain to the final course evaluation that all students must complete at the end of the semester.

Overall, the ESH domains emphasized most in the current biology curriculum are Domain 1: Characterizing Health at the Animal-Human-Environment Interface, Domain 3: Systems Thinking, Domain 4: Communication, and Domain 7: Modes of Inquiry. The domains with the least emphasis in the Biology Department courses are Domain 2: Diversity, Equity, Inclusion, and Justice in Ecosystem Health, Domain 6: ESH Project Management, and Domain 9: Values, Morals, and Ethics.

This student-led analysis of the Biology Department curriculum has led to some key findings that shed light on potential improvements that can be made to existing curricula:

- The relatively low scores for Domain 2 and Domain 9 suggest that either a new course be added or a modification to current curricula be made that emphasizes moral and ethical discussion. It must also include the examination of underrepresented and non-western perspectives.
- Environmental Chemistry is not currently required for the Biology (EEB) major, but we recommend that it becomes a core class to address how anthropogenic influences alter water, air, and soil chemistry and broader ecosystem impacts. The course, ESG 2005, Environment and Sustainability, from the Geography Department, could also be added to address the intersectionality of these topics.
- To bolster students' abilities to ask critical questions and find answers to scientific questions; one recommendation is to start teaching techniques on reading primary literature to students earlier in the core courses such as General Biology 1 and 2.
- Regarding gaps in Integrative Leadership (Domain 5), we recommend that an internship course be emphasized or required to give students the opportunity to both work on their personal project planning and self-leadership as well as work in a group to meet a shared goal. Interpersonal Communication is a course from another program that we recommend.
- ESH Project Management (Domain 6) is not emphasized in the core curriculum due to the introductory nature of these classes. Courses with laboratory sections have the widest opportunity for growth in this area by explaining the process of how real research is conducted and asking students how they might approach different projects. Allowing students to interact with real researchers outside of the University and speak with experts who have managed their projects could also increase competency in this domain. A course that could be used to supplement this category would be EES 4102, Environmental Assessment.

- For Knowledge to Impact (Domain 8), the curriculum could better meet this domain if more of an emphasis was placed on relevance: *why* are we learning this material? Courses could also incorporate how individuals could make an impact and what types of careers would allow them to do so. An additional course for supplementation would be ANTH 1620, Introduction to Public Culture: Earth Citizenship, Science, and Culture.

We believe that these recommendations could improve the overall experience of Biology students at UMD. Producing scientists who are interdisciplinary and competent in their knowledge of sustainability will be crucial in an ever-changing world with issues such as climate change and environmental injustice.

## **Discussion**

There has been a recent emphasis on ecosystem health and sustainability in undergraduate education. Whereas some programs were created towards this end, others have been modified from more traditional STEM disciplines, including biology. Having a mechanism to determine the effectiveness of these programs in educating our students is paramount. We employed the ecosystem health competency framework (EHCF) created by the Ecosystem Health Working Group of the University of Minnesota's Institute on the Environment (Colombo et al., 2023) to evaluate the Biology curriculum at the University of Minnesota-Duluth. Although the Department of Biology faculty did not consider this framework during the creation of courses and curriculum (it did not exist), we felt this to be a useful metric to determine how well it prepares students to effect change in the areas of ecosystem health and sustainability. The framework and the use of undergraduate students to perform the assessment were both effective. This strategy should be considered by other institutions wishing to evaluate their program's effectiveness.

The framework we employed for our assessment was designed to help emerging and existing programs develop curricula to prepare students in ESH and to create a shared language across curricula. A team created it following a literature review of articles focused on ESH, interviews with ESH practitioners, inspection of ESH job postings, and examination by focus groups (Colombo et al., 2023). It is composed of 9 domains (Table 1) that represent the breadth and depth of knowledge and skills necessary for students to develop as practitioners in the field. While no single course in a curriculum would be expected to fully meet all 9 domains, a curriculum focused on ESH and sustainability should.

Undergraduate students were effective as evaluators and in determining the next steps to establish a sustainable curriculum. Using undergraduate students as evaluators of curriculum eliminates a bias that would be present with self-evaluation of an instructor's own curriculum. Also, student-led curriculum evaluation allows us to view the presence of sustainability teaching from the perspective of the student. Importantly, student evaluations of teaching carry their own set of biases. For instance, Student Rating of Teaching (SRT) evaluations, more commonly known as Student Evaluations of Teaching (SET), are shown to carry biases against instructors based on language (Ogier, 2005), race (Chávez & Mitchell, 2020; Reid, 2010), sexual orientation (Ewing et al., 2003), and gender (Chávez & Mitchell, 2020; Mitchell & Martin, 2018; MacNeill

et al., 2015), especially in the sciences (Fan et al., 2019). We acknowledge that we are not immune from these unconscious biases, so this is a limitation of the study. However, we believe that our student-led approach to department-wide curriculum assessment was highly effective because it has the advantage of analyzing the *content* of courses as opposed to the *instructor*. Furthermore, distinguishing between core courses and electives allowed us to understand where along a Biology student's academic path they would encounter gaps in different domains. In future studies, it would be interesting to explore whether gaps in different domains for the core courses have any impact on the retention of students in the Biology major. The student-led approach we utilized allowed us to identify these gaps and assess the sustainability of a department's curriculum from an EHCF lens.

With these gaps present, it is important to address how to keep students invested in sustainability curricula. Previous work done by Teather & Etterson (2023) at the University of Minnesota Duluth found that students earlier in their education were more interested in learning about sustainability curricula than upper-division students. The authors did mention that off-campus students, who are usually further along in their degrees, showed higher non-curricular sustainability-oriented behaviors like activism/local shopping (Teather & Etterson, 2023). However, it would be interesting to see if there is some other reason that interest in sustainability courses decreases as students progress in their degrees. We are interested to see if filling in these domain-based gaps in the core courses could help retain interest in sustainability curriculum as students progress through their degrees.

Another important question remains: how can we incentivize maintaining EHCF principles in the curriculum in the future? As we addressed before, SETs are inherently biased, so we cannot recommend any additions of EHCF-driven questions to SET evaluations at this time. Furthermore, these focus on evaluations of teaching and not the curriculum itself (Zabaleta, 2007). Also, the literature is much more scarce on student evaluations of curricula; student feedback seems to be typically focused on the quality of teaching and instruction itself. Therefore, there is an underutilized opportunity to implement student-led evaluations of curricula, but these evaluations must be designed to reduce biases and disparities faced by instructors.

Overall, this study provided a unique lens in viewing an academic department's entire curriculum to see if certain sustainability-related domains were being addressed. By doing so, the student evaluators in this study identified domain-based gaps in the Department of Biology's curriculum. From there, we recommend adding certain courses that can help remediate these gaps and suggestions to improve the current curriculum offered by the Department. With the EHCF's main objective of developing a curriculum that emphasizes a holistic approach to sustainability, these results offer context as to how the current Department of Biology curriculum could be improved to meet these different domains' objectives. We believe our model to be a potentially useful and effective tool that other schools and institutions could adopt/adapt. Future work should explore how to promote the incentivization of EHCF principles into curriculum, and how curriculum can transform the widespread feelings of climate anxiety into transformative action.

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