The Future of Engineering Education
2024 Annual Conference & Exposition

Oregon Convention Center
Portland, OR . June 23 - 26, 2024

ASEE

Paper ID #43380

Introducing Social and Environmental Sustainability Aspects Cohesively throughout the Student Experience: One Course at a Time while Considering the Program as a Whole

Dr. Elisabeth Smela, University of Maryland, College Park

Elisabeth Smela is a Professor of Mechanical Engineering at the University of Maryland. She received a BS in physics from MIT and a PhD in electrical engineering from the University of Pennsylvania. Previously, Dr. Smela had worked as a research scientist in Linköping, Sweden and in Risø, Denmark before becoming Vice President of Research and Development at Santa Fe Science and Technology, NM. Dr. Smela's research interests are focused on polymeric and cell-based sensors and actuators. She has served as Associate Dean for Faculty and Graduate Affairs, Equity Administrator, and Diversity Officer, and she then served a year as a Jefferson Science Fellow at the Department of State to stand up the US-ASEAN Smart Cities Network. She has recently been working with a group of engineering faculty to better integrate sustainability concepts throughout the curriculum.

Dr. Vincent Nguyen, University of Maryland, College Park

Vincent P. Nguyen is a Senior Lecturer at the University of Maryland, College Park. He is a founding member of the Environmental and Socially Responsible Engineering (ESRE) group who work to integrate and track conscientious engineering aspects throughout the undergraduate educational experience across the college. His efforts include formally integrating sustainability design requirements into the mechanical engineering capstone projects, introducing non-profit partnerships related to designs for persons with disabilities, and founding the Social/Environmental Design Impact Award. He manages several outreach and diversity efforts including the large-scale Get Out And Learn (GOAL) engineering kit program that reaches thousands of local K-12 students.

Dr. Natasha Andrade, University of Maryland, College Park

Dr. Natasha Andrade is a Senior Lecturer and the Associate Chair for Undergraduate Studies in the Civil and Environmental Engineering Department at the University of Maryland College Park. Her responsibilities include overseeing the undergraduate program and teaching various undergraduate courses in civil and environmental engineering.

Andrew Elby, University of Maryland, College Park

Andrew Elby's work focuses on student and teacher epistemologies and how they couple to other cognitive machinery and help to drive behavior in learning environments. His academic training was in Physics and Philosophy before he turned to science (partic

WIP: Introducing social and environmental sustainability aspects cohesively throughout the student experience: One course at a time while considering the program as a whole.

This WIP paper outlines the approach of introducing sustainability elements integrally throughout a curriculum at a large mid-Atlantic R1 university, the University of Maryland, College Park. Sustainability is considered broadly to include the three pillars of sustainability - environmental, social, and economic - but also explicitly addresses aspects from the Engineering for One Planet (EOP) framework - systems thinking and critical thinking - as well as diversity, equity, and inclusion (DEI) and student agency or empowerment to act. These curricular aspects are often relegated to isolated assignments, and the current approach is to instead thread these aspects cohesively throughout the entire four year student experience. The effort includes faculty training, individual course modifications, the addition of new courses and student experiences, and programmatic assessment.

A faculty workshop was conducted in winter 2023 that introduced sustainability concepts and tools. Division leaders and instructors of key required courses were specifically enrolled. Individual course modifications were proposed, but within the context of understanding and mapping out the entire student experience across all required undergraduate classes. This paper discusses the shift toward developing an active community of practice, the development of a sustainability teaching certificate, managing individual course modifications, identification and mapping of relevant learning outcomes throughout the required curriculum, programmatic assessments, and work toward sustainment of the effort by providing valued assessment reporting.

Introduction to the sustainability curriculum effort

Since 2020 a small group of faculty at the University of Maryland (UMD), College Park have been working toward preparing engineering undergraduates to become both willing and able to tackle sustainability challenges. Sustainability is considered broadly to include the three pillars of sustainability: environmental, social, and economic. In our effort we also address topics from the Engineering for One Planet (EOP) framework [1], in particular systems thinking and critical thinking, and we explicitly consider diversity, equity, and inclusion (DEI) as well as student agency, or the feeling of empowerment to act. The effort is multi-faceted and includes curriculum changes, faculty training, and assessment. The implementation is eventually intended for all departments across the college of engineering, and there has been interest from multiple units. However, the initial focus has primarily been on Mechanical Engineering, the largest major within the college, because it is the home unit for the majority of the faculty team.

Part of the approach includes providing project-based opportunities, focusing on projects that can have positive impact and go out into the public domain [2]. These efforts target student empowerment, providing real-world opportunities to exercise engineering skills toward positive "do-ing", and creating these opportunities within the undergraduate experience. The implementations are necessarily multi-disciplinary and address the intention of de-siloing engineering approaches in the context of broader socio-technical solutions. Assessment of programmatic goals is another necessary and challenging aspect, and is also being considered [3].

Curriculum development and curriculum modification have comprised significant portions of the approach. A goal of the team is the meaningful implementation of sustainability considerations in all required undergraduate courses. Although the importance of these aspects is widely acknowledged by faculty in the authors' departments, as gleaned through conversations and interviews, ability and confidence in introducing these topics within traditional coursework is lacking. Firstly, faculty are often unfamiliar with basic sustainability concepts (e.g. it's not just about global warming) and information (e.g. the UN SDGs, the IPCC). Secondly, faculty have not only not been trained in these topics, but also have not been trained in teaching them effectively, and they do not generally have the time required to learn that independently. Thirdly, it is not usually obvious how these topics can be sensibly integrated into various courses without appearing to be extraneous add-ons. *Thus, faculty training and support are important components of curriculum transformation activities.*

There have been "train the trainer" efforts utilizing faculty workshops to introduce sustainability concepts [4,5], and the initial approach at UMD was a four-day faculty workshop implemented during the 2023 winter term. The workshop was developed for key leadership and instructors of required undergraduate courses. The workshop concluded with numerous positive outcomes [6]. However, the sustainment, growth, and effectiveness of the training could potentially be improved with format changes, and the evolution of the faculty training effort is the topic of this paper.

How our curricular modification approach fits into the landscape of department-wide change efforts

The winter workshop and community of practice described in this article constitute part of department-wide curriculum modification effort. In this section, we describe how our unusual approach to this effort fits into the broader landscape of department-wide curriculum change approaches toward addressing sustainability more deeply and consistently across courses.

One dimension along which such efforts vary is the mix of top-down vs. bottom-up initiation of the change efforts. In top-down approaches, department leadership either decides on or initiates a process for deciding on the direction of the curricular changes. For example, in their article *Integration of Education for Sustainable Development in the Mechanical Engineering Curriculum* [6], the authors describe a leadership-initiated "process that started with the formulation of program vision and program level learning outcomes. Faculty meetings and workshop were used to formulate the course learning outcomes and to map the program level outcomes to courses in which the outcomes are satisfied followed this." Similarly, the University College London Faculty of Engineering Science undertook a multi-year program update in which "strong leadership at faculty level…initially drove the initiation of the educational change programme and the definition of the high-level vision" [8]. By contrast, other change efforts begin bottom-up with highly-motivated faculty members leading the charge. However, as documented in a multi-institution study of curricular change efforts in engineering departments [8], *purely* bottom-up approaches confront obstacles in convincing a critical mass of faculty to buy in and participate. For instance, at the University of Alabama, "there was some support from the dean and the provost, but for the most part it was a bottom-up effort, being pushed by the faculty who developed the curriculum. This was not an effective strategy" (p. 5) [9]. But neither is a purely top-down approach, if faculty don't buy in. Indeed, the curricular change efforts described in [7] and [8], though *initiated* by leadership, also involved substantial bottom-up refinement and implementation. The authors of [10] agree with several researchers that both top-down and bottom-up processes are needed in a successful curricular change initiative.

The curricular change efforts presented in this work initially began as—and largely remain—a bottom-up effort, initiated and led by passionate faculty members. However, involvement of College leadership in the activities described below provides a pathway by which top-down processes could become part of the initiative.

A second dimension along which department-wide curricular change efforts vary is the depth with which sustainability gets incorporated into the curriculum. As [11] lays out, such efforts can be categorized along a spectrum of increasing emphasis on sustainability. Reference [8] summarizes Sterling's three levels along this spectrum.

> "1. Education *about* sustainability is an assimilation strategy where sustainability subjects are included in the formal curriculum. There is no change of educational paradigm. This is an *add-on* strategy… 2. Education *for* sustainability includes content and values, and will involve some modifications of the program, but the

educational paradigm remains intact. This leads to an *integration* strategy... 3. Education *as* sustainability is a transformative, epistemic learning response and will involve an educational paradigm shift involving the whole learning person and the entire institution (or at least a whole Faculty or School). This requires a re-build strategy for the curriculum and for the organisation." (p. 51)

As described below, our efforts strive for level 2, an integration strategy, and fight against the tendency of such efforts to slide back toward level 1, a loosely-coupled collection of add-ons to existing courses and course sequences. Longer term we hope to pursue level 3, a deeper transformation of the undergraduate program, though of course this requires extensive involvement of leadership-sustained top-down processes.

Faculty workshop and the formation of a sustainability community of practice (SCOP)
In January 2023 a four-day faculty workshop was held over the winter break as described in [6, 12] The workshop included 10 faculty participants who had not previously been involved with sustainability efforts, of whom three were undergraduate program directors. The breadth of content included an overview of basic concepts (such as the triple bottom line and the United Nations Sustainability Development Goals), engineering-oriented tools (such as life cycle assessment, LCA), several guest speakers on the topic of DEI, pedagogical methods (such as socio-technical approaches and the use of artifacts as examples), and discussion of meaningful assessment approaches. The event was held away from the Engineering buildings in a venue with transformable seating and discussion formats tailored for each activity, facilitating full focus and involvement. Particular attention was paid to the daily lunches as an opportunity to build community and demonstrate sustainability behaviors. The workshop culminated with planned course modifications that were to be implemented during the following Spring and Fall semesters.

The participants found the immersive experience powerful and motivating. However, the four-day time commitment proved to be daunting, for both participants and organizers. For best possible participant availability the workshop was held during an academic break on consecutive days. However, the short calendar span was not conducive to in-depth reflection or detailed course planning, and there was definitely no time for implementation and testing. Although enthusiasm was high after the workshop, the beginning of the spring academic semester quickly pushed planned activities to the back burner, and momentum fizzled. Course assignment changes and changes in faculty positions further complicated implementation of the course changes planned during the workshop. In addition, the planning and presentation of the workshop content was up to the organizers, and this workload burden is difficult to maintain or scale.

During the faculty workshop, attendees expressed strong interest in continuing their involvement with each other to maintain momentum in a sustainability community of practice (SCOP). In Spring 2023, the organizers solicited feedback via an email survey on specific ideas for the group to pursue, including pedagogy, course development coaching, class observations, and use of sustainability tools such as life cycle

assessment. The organizers also shared a summary of the course change plans that workshop participants had created during the workshop. The hope was that SCOP would be able to support implementation of those plans. In addition, multiple topics were set up on the messaging app Slack. The idea was to use the app to get updates from faculty on how course integrations were being implemented and to show that there was a fan group ready to cheer them on.

These electronic means of communication proved to be ineffective. While one SCOP member shared Granta case studies available through Ansys, information on sessions that could be of interest at the ASEE annual conference, and an extra credit assignment introduced into a course, others did not participate on the app. It would seem that the crush of electronic messages that faculty already receive made the effort of specially seeking out further messages on another platform unattractive, particularly during the semester.

Thus, the organizers shifted to the idea of inviting each faculty member to one-on-one peer mentoring sessions to discuss their course changes. The approach had merit as specific implementation challenges to be directly addressed. Despite the hurdle of limited time to take this on, some meetings were held, and these proved to be helpful. This one-on-one followup would be difficult to sustain as it relied heavily on the core team, and the workload would proportionally scale as more faculty and course modifications come on board.

In Fall 2023 the organizers set up meetings every month, changing the day of the week and time to try to accommodate as many SCOP members as possible, with topics such as assessment and critical thinking. In addition, to hold faculty accountable for the changes that were promised, it was determined that workshop attendees would be invited to present what they had done. It was here that the biggest challenge to implementing SCOP became apparent: the lack of overlapping times when faculty were available. Scheduling polls showed that at most approximately 40% of the members (8 people and a couple of the organizers) could attend. A lunch was organized to close the semester, which was attended by approximately the same number of people. While SCOP members said they valued the meetings, the small size of each group and different individuals attending each meant that strong cohort coherence was not maintained.

Toward the end of Fall, the organizers also put together a template for reporting course change implementations. The idea was to collect complete and uniform information about what has been done. The extent of the required information meant that it took several hours to complete the form for every change. This barrier will likely need to be addressed. An initial approach of having organizers meet with everyone one-on-one was again taken up, with some amount of success. Maintaining the momentum over end-of-semester frenzy, holidays, and intensive January teaching and travel was once again challenging.

After the Fall 2023 semester it was clear that SCOP required more significant management. The spaced-out meeting dates provided opportunity for implementing course changes. Sharing-out and discussions presented opportunities for participants to become engaged in content delivery and coaching. This engagement is hoped to increase faculty agency and spread the teaching resources and workload across the SCOP community. This approach also provides the possibility of scalability. Thus, for 2024 the plan was to migrate the workshop content to the SCOP meetings.

The decision was made to forgo additional workshops in lieu of planning and managing the SCOP meetings to better facilitate course modifications. This meant that the SCOP meetings would now need to include content and tools that were presented in the workshop (such as LCA analysis, DEI considerations, socio-technical thinking, and assessment and pedagogical techniques). Additionally SCOP would need to formally integrate the course modification activities and reflection.

In January of 2024 we consulted with the SCOP group. A plan emerged to hold meetings more frequently, every two weeks, and to hold them at two different times during those weeks so that nearly all members would be able to attend most weeks. Members said they were interested in (1) hearing about what others in the group had tried in their courses and (2) revisiting the tools that had been introduced during the workshop to gain greater familiarity with them.

<u>Sustainability teaching certificate</u>
To recognize faculty engaged in this work, the team pursued the idea of issuing a teaching certificate that would be recognized by the Dean. The certificate would highlight faculty who have learned about, and committed to implementing, sustainability-driven activities and assignments in their courses. The aim of the certificate is to create a culture change among the engineering faculty by growing the number of faculty members who feel confident incorporating different pedagogical strategies to demonstrate how sustainability considerations can and should be incorporated into engineering design decisions. The hope is that a critical mass of faculty, including key influencers, will come to see that environmental and social sustainability can be meaningfully infused throughout the curriculum, not as abstract concepts but in terms of decisions that engineers make directly using their course material. This approach is centered around the idea that sustainability should be infused throughout the curriculum because it is a fundamental responsibility of engineers. Moreover, students require these skills in order to take thoughtful actions at decision points in their careers. A subset of the team of faculty who organized the workshop, plus an important addition to the team, a member of the university's Transformation & Learning Transformation Center (TLTC), is responsible for creating the content of the certificate, implementing it, and managing it.

The certificate system being considered is formatted to be consistent with a planned teaching academy being developed by the TLTC. The team has been awarded a grant from TLTC to explore how unit-specific certifications can be co-developed and expanded across the university. The focus of this effort is to develop a certification that

makes sense in engineering, but then to explore expansion to other units across the university.

The team is considering a two-level set of accomplishments for the certificate. Though the specific content of the certificate is currently under development, the team put together what each level of the certificate could look like. Each level would include 4 steps that would be required for completion. An outline of the certificate plan follows.

Level 1
In Level 1 of the certificate, faculty members will be asked to investigate and plan a curriculum change in one of their courses. Along with this, faculty members will be asked to crowd-source in which courses sustainability outcomes are being taught or introduced. The goal is to keep in mind that these changes need to be implemented at all levels of a particular curriculum. Moreover, it is likely that some of the EOP-related outcomes may already exist in some courses, therefore it will be useful to map these to gain a more clear picture of the extent of the required new implementations.

1. Sustainability LOs and LO mapping
   - Learn about Engineering for One Planet learning outcomes [12, 13] and existing sustainability/DEI/agency outcomes currently being used by the SCOP group.
   - Add any known courses and content to the existing LO mapping, which tracks courses throughout the 4 year student experience that include sustainability elements.
   - Identify and create learning outcomes (LOs) for their own course and consult with TLTC to revise LOs for the course and create LOs for particular assignments.

Deliverables: identify (and/or confirm) existing LOs within the 4 year curriculum (and their own course currently) and identify or create new LOs for the course or for an assignment.

The teaching certificates will result in course modifications within individual courses, but to thread them throughout the student experience requires a reflection on programmatic LOs and the role of the individual course within the degree. Course activities identified by participants will be documented and tracked, building a comprehensive picture of sustainability across the program (information that has traditionally been difficult to gather and update). This information will be disseminated to the units via sustainability program reports that will aid in accreditation and LO assessments reports, providing a foundation for support and sustainment of the effort.

2. SCOP participation
   - Attend in-person SCOP discussions about the tools that can be used in engineering courses.
   - Look up additional relevant examples of course modifications of sustainability content and tools that could be integrated into course work.
   - Attend SCOP discussions of examples of what other faculty members have done in their classes.

Deliverables: submit a reflection which could include answers to questions such as 1) How did the example or tool spark your creativity?; 2) What are the pros and cons of this tool or example?

3. Assessment
   - Attend SCOP discussions about assessment and look up additional relevant assessment research; or attend SCOP discussion about general pedagogical approaches and look up relevant pedagogical approaches.

Deliverables: Submit a report on the research.

4. Course implementation plan
Develop an implementation plan for a course change.

Deliverable: Detailed plan for classroom implementation, which should include collecting student feedback.

Level 2
In Level 2 of the teaching certificate, faculty members are required to implement and reflect, including how these changes will become an integral part of the course, particularly if there is a change in instructors.

1. Implementation Reporting
Report the implementation and analysis of student feedback to SCOP.

Deliverable: a short presentation and discussion with SCOP.

2. Research
Research on the topic of their choice using the tools, skills, and/or information provided by the certificate (examples: LCA, pedagogy, circular economy) or something else chosen by the faculty member.

Deliverable: A reflection that includes how the research tools can be incorporated into the classroom.

3. Sustainment
Develop a robust implementation plan for a more meaningful course change, which includes an assessment plan.

Deliverable: Detailed plan for classroom implementation. The deliverable needs to include a sustainment plan, i.e. how these course changes remain as a part of the class in the long term, particularly with an instructor change. Considerations should include how the assessments created here could be tied to ABET or University Learning Outcome Assessment reports.

<u>4. Final Documentation</u>
Report back to SCOP, submit to our archive.

Deliverable: All course material, assessments, and reflection.

Reflection and continuation of the effort
Concrete next steps for the work are the launching of the certificate program. In addition, the team continues to work toward determining how to best support and learn from each other during the course of the school year. The willingness is there, but the logistics are a problem. Yet this effort is critical because while some changes have been made to courses, they remain small, in the nature of small extra credit assignments that are not well integrated and not well assessed. The next steps of making more serious changes must be tackled. This has occurred in one course, capstone design, because three of the core team are involved in teaching it. For example, quantification of environmental impacts (e.g. using life cycle assessment) and positive social impacts is now required, but it is late in the curriculum to introduce these concepts, which would be better shifted to the first year. The requirement for faculty to develop appropriate material for each course is a significant barrier, which we hope that SCOP can help overcome.

In general, a community of practice is needed in order to keep the conversation moving forward, to normalize and support the thinking about how to teach these topics, and to provide a forum for exchanging ideas and information. This is something that can be applied in other universities, respecting the scheduling barriers identified previously.

Regarding the teaching certificate, while the implementation details may be unique to UMD or to the education platform on which it is hosted, the requirements and developed content are transferable to other institutions. A format for self-timed learning and the key concept of having the activities centered around actual course modifications, with eyes external to the course giving feedback (via the SCOP) is generalizable. This is a long-term goal of our work, since sustainability needs to become an integral part of education broadly, in fact worldwide and not just confined to engineering.

Program success could be defined by having sustainability elements incorporated meaningfully into all required courses within the curriculum, with concepts being appropriately scaffolded and revisited through the multi-year student experience. The goal is to develop a process and community that is directly utilizable across the college of engineering, but could also expand across campus and to other institutions.

In conclusion, while the effort to integrate sustainability into an engineering curriculum may be more challenging than initially thought because of various barriers, it is possible to consider multiple models for supporting faculty to do so, which can be used singly or in combination. As the various networks of instructors strengthen and expand, we will be able to share successful approaches and pitfalls, pedagogical practices, assignments and student experiences, and learning outcomes measurement so that these efforts can become more effective.

References

[1] The Lemelson Foundation, "The Engineering for One Planet Framework: Essential Learning Outcomes for Engineering Education," online, (updated in 2022) 2020. https://engineeringforoneplanet.org/wpcontent/uploads/eop_engineering-for-one-planet_framework.pdf

[2] Nguyen, V., & Smela, E. (2023, June), Board 137: WIP: Engaging Mechanical Engineering Students in Projects of Caring: Socially and Environmentally Responsible Projects that Go out into the Public Domain Paper presented at 2023 ASEE Annual Conference & Exposition, Baltimore , Maryland. https://peer.asee.org/42457

[3] Andrade, N., & Smela, E., & Nguyen, V., & Bigio, D., & Egyen-Davis, A., & Nganjo, D. (2022, August), Environmentally and Socially Responsible Engineering - Assessing Student Empowerment Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/41569

[4] S. Hoffmann, I. Hua, E. Blatchley, and L. Nies, "Integrating sustainability into courses across the engineering curriculum: a faculty workshop model," in ASEE Ann. Conf. Expo, Louisville, KY, Jun 20-23 2010, pp. AC 2010-1802, 15.773.1, doi: DOI:10.18260/1-2--16732. https://peer.asee.org/16732

[5] A. L. Welker, V. Smith, S. Shrestha, and K. M. Sample-Lord, "Including principles of sustainability in design by implementing the engineering for one planet framework," in ASEE Ann. Conf. Expo., Minneapolis, MN, June 26-29 2022, p. Paper ID #37048. https://peer.asee.org/40926.

[6] Smela, E., & Nguyen, V., & Bigio, D., & Andrade, N., & Mogul, N., & Tomblin, D, & Elby, A. (2023, June), Faculty workshop on teaching sustainability, Program Paper presented at 2023 ASEE Annual Conference & Exposition, Baltimore , Maryland. https://peer.asee.org/faculty-workshop-on-teaching-sustainability.pdf

[7] Enelund, M., Knutson Wedel, M., Lundqvist, U., & Malmqvist, J. (2013). Integration of education for sustainable development in the mechanical engineering curriculum. Australasian Journal of Engineering Education, 19(1), 51-62. https://doi.org/10.7158/22054952.2013.11464078

[8] Mitchell, J. E., Nyamapfene, A., Roach, K., & Tilley, E. (2021). Faculty wide curriculum reform: the integrated engineering programme. European Journal of Engineering Education, 46(1), 48-66. https://doi.org/10.1080/03043797.2019.1593324

[9] Merton, P., Clark, C., Richardson, J., & Froyd, J. (2001, June), Engineering Curricula Change Across The Foundation Coalition: How They Succeeded, What They Learned.

Paper presented at 2001 Annual ASEE Conference, Albuquerque, New Mexico. 10.18260/1-2--9185

[10] Mulder, K. F., Segalas, J., & Ferrer-Balas, D. (2012). How to educate engineers for/in sustainable development: Ten years of discussion, remaining challenges. International Journal of Sustainability in Higher Education, 13(3), 211-218. https://doi.org/10.1108/14676371211242535

[11] Sterling, S. (2001). Sustainable education: Re-visioning learning and change. Schumacher Briefings. Schumacher UK, CREATE Environment Centre, Seaton Road, Bristol, BS1 6XN, England. http://eric.ed.gov/?id=ED464791

[12] E. Smela, V. Nguyen, D. Bigio, N. F. Mogul, N. Andrade, and A. Elby, "Faculty workshop on teaching sustainability in engineering," Eleventh International Conference on Engineering Education for Sustainable Development (EESD2023), Fort Collins, CO (June 18-21, 2023).

[13] Engineering For One Planet. "About EOP." https://engineeringforoneplanet.org/ (accessed February, 2023).