Principles of Environmentally Responsible Engineering:

2019 Roundtable Summary and Lessons

Supported by The Lemelson Foundation
Prepared by VentureWell

EXECUTIVE SUMMARY

Though the benefits of environmental responsibility are increasingly recognized by individuals across many sectors of our society, neither the principles of environmental responsibility nor the tools of sustainable design are widely integrated into science and engineering curricula. As a result, too few students have the opportunity to develop these important skill sets.

With this in mind, The Lemelson Foundation and VentureWell designed and co-hosted *Principles of Environmentally Responsible Engineering: Creating a Roadmap for Change*, a two-day roundtable which convened 20 leaders from across higher education, nonprofit, business, and government. These 20 experts, who were already deeply engaged in incorporating sustainable engineering into their work - including through research, teaching, and invention as well as in spreading this approach within their fields - came together with the aim of creating a roadmap for defining and developing a framework for "environmentally responsible (ER) engineering."

Throughout the two days, participants engaged passionately - sharing their personal experiences and challenges, reflecting on the urgent need to identify scalable levers for impact, and grappling with the inherent value of creating a framework for ER engineering. Some participants felt that there were existing frameworks that could be used, others thought a framework would not go far enough to make all of the necessary changes, and still others felt a framework could become too prescriptive. In the end, however, a shared enthusiasm for making progress led to general agreement that collective action was needed. Together, roundtable participants generated a high-level list of questions that need to be answered and stakeholders that need to be engaged to develop and drive forward a framework for the concepts, values, and skills all engineering students need to learn in order to engineer with the health and sustainability of the planet in mind.

At the conclusion of the event, participants provided a series of clear recommendations for action, including the creation of a strategic document that clarifies the rationale and urgency of this work, and sets and ultimately refines parameters for a framework that clarifies what ER engineering is as well as the core questions, goals, and values that define it. Participants also recommended developing comprehensive communication tools and a repository of existing sustainability frameworks and other relevant resources. They also cited 2019 as a clear window of opportunity for establishing a timeline of critical milestones and deliverables for the future of this effort and expressed their enthusiasm about taking part in future activities.

BACKGROUND

As the world needs more creative solutions to the pressing environmental problems we collectively face, it is critical that engineering students learn and are taught in ways that ensure their inventions and innovations are designed, developed, and distributed in sustainable ways. Specifically, while playing a significant role in solving current and future global environmental and social issues, product inventors and engineers can also contribute to unintended negative impacts on the environment. To minimize those potential results, the inventors, engineers and product designers of tomorrow would benefit from knowing how to apply principles of environmental responsibility throughout the design and commercialization process. Engineering education is a key lever for change - yet an understanding of the principles of sustainability, and the skills needed to implement them, have not been integrated into educational preparation for the vast majority of engineering students. A clear opportunity therefore exists to forestall future unintended negative impact by preparing future engineers and designers to invent with our planet in mind.

Successful curricular approaches have been developed in some fields – chemical engineering and green chemistry are pioneering in this regard, and there have also been efforts within a variety of other engineering disciplines[1] – yet ubiquitous exposure to environmental responsibility remains a critical challenge. It is especially challenging at the undergraduate level, where a large number of students are first introduced to the professional disciplines, form their identity as inventors and innovators, and have the opportunity to develop and test their ideas in the lab or field for the first time. Fostering literacy among all engineering students, throughout their studies and coursework, in the principles of environmental responsibility is imperative in order to address urgent societal needs and to understand the potential environmental benefits and unintended negative consequences associated with their inventions and innovations. A greater understanding of these fundamental principles will also better prepare emerging engineers with the vocabulary, tools, and practical thinking skills to drive transformative developments in the 21st century and beyond.

In a research report published by The Lemelson Foundation (The Foundation) in March 2018, *Teaching Environmentally Responsible Inventing: Higher Education Environmental Landscape Research and Analysis*, one high-priority recommendation was to "invest in faculty by supporting their development and education." This investment is particularly important given that adoption of new educational approaches is often difficult. Ongoing infrastructure to foster longitudinal connections between and among faculty is also recommended – to ensure implementation of knowledge, to support faculty as they test these new approaches with learners, and to foster the propagation of sustainable design principles to additional faculty and higher education professionals both within and beyond STEM disciplines[2].

With all of this in mind, and to further its commitment to enabling the next generation of product inventors to address a range of urgent social and environmental problems while ensuring their inventions and business models are also sustainably designed and environmentally responsible, The Foundation identified an important need to support a convening of key stakeholders to define ways of deepening and more broadly embedding the principles of environmental responsibility into engineering education. The Foundation took engineering to be a natural starting point because engineering disciplines generate a large proportion of the inventors and innovators whose technologies will transform our world, and engineers are responsible for scaling inventions through manufacturing.

ROUNDTABLE CONTEXT AND PLANNING

The *Principles of Environmentally Responsible Engineering* roundtable took place on March 27-28, 2019 in Washington, D.C. immediately prior to VentureWell's 2019 OPEN conference. The meeting was co-hosted by The Foundation and VentureWell and was facilitated by the Academy for Systems Change. Twenty experts from across higher education, industry, government, and philanthropy convened for the intensive, interactive event. Invited participants were identified as having both a high level of existing expertise and experience in their respective fields, and established commitments as champions of environmental responsibility, not only within their own work but also across broader spheres and systems of influence. The participant selection process was based on a combination of research and pre-existing connections, as well as an intentional focus on attendees from engineering disciplines and an effort to achieve diversity across gender, ethnicity, and geography.

In advance of the roundtable, organizers conducted interviews with 19 of the 20 participants. The interviews centered around 12 questions (see Appendix A), posed with the aim of understanding the current reality of ER engineering, the future desired state, and possible actions that could be taken to bridge the two. The data from these interviews were collated and summarized in a document that was shared with participants ahead of the roundtable, along with a list of recommended resources generated from participant interviews.

The roundtable itself focused on achieving three key results:

1. **A connected community with a desire to be part of this work** going forward
2. **An initial, high-level list of framework elements**, inclusive of:
    - An understanding of what engineers need to be able to do to be environmentally responsible
    - A preliminary, high-level list of core competencies that engineering students therefore need to learn in order to be environmentally responsible in their impact on the world
    - Experiences that will enable students to gain the needed knowledge
3. **A roadmap** which includes:
    - Specific recommendations for next steps for developing a framework that will be validated by stakeholders and be used to accelerate the integration of environmental responsibility in engineering education
    - Suggestions for tactical ways to raise awareness of the project in the higher education engineering community, both within individual institutions and across multiple campuses, as well as among key stakeholders in industry and professional associations
    - Recommendations for additional stakeholders to engage and ideas for raising their awareness and engagement
    - Specific commitments and actions from participants to move forward from this meeting

KEY ELEMENTS OF THE ROUNDTABLE

DAY ONE

From the very beginning of the event, roundtable participants identified some areas of initial alignment and shared context from which to begin a rich dialogue (see Appendix B for a full meeting agenda). These included an acknowledgement that while there has been some progress in the integration of environmental responsibility into engineering curricula, there is still much work to be done—and there is also inspiration to be found in the progress made in integrating new ideas in other domains, such as innovation/entrepreneurship and ethics, both of which were once seen as outside of core learning objectives but are now much more widely recognized, valued, and integrated within higher education curricula. Other framing principles offered by the participants included a "healthy impatience for change" and a desire to move from "chase mode" to "build mode" (i.e. shifting from conceptual to tactical strategies for integrating environmental responsibility into engineering education).

After the participants exchanged introductions, they heard a presentation from The Foundation's David Coronado, describing a multi-year effort around K-12 Invention Education that bore some significant process similarities to the challenges and opportunities of widely integrating environmental responsibility into engineering education. Through an interactive dialogue, participants shared a number of key insights, including the importance of

- naming (or branding) the initiative,
- being intentional in choosing the right stakeholders, and
- ensuring space for collaboration between multiple disciplines

One other shared insight included the need to take a "principled approach" to the work - i.e. although it is important to acknowledge that a given set of principles may evolve over time, it is still critical to set a clear vision for the work based on the current landscape, and to identify core elements and tactics that can be tried and iterated upon.

Following this presentation and discussion, participants engaged in a facilitated conversation on their hopes for the future of engineering education. One theme that arose was around the inherent need (or not) for creating a framework, as described in desired meeting result #2. There were many divergent views expressed with regard to the need for a framework, as well as on the use and definition of the word "framework." This manifested in multiple ways. Some participants cited the existence of many other frameworks already published on related topics, while others expressed a preference for focusing on learning objectives over a framework that could prescribe "what exactly to do or how to do it."

With these views in mind, the group discussed ways in which a new framework might be created to draw from and build upon existing frameworks and resources, in order to serve a new need – specifically, to identify the principles, knowledge, skills, and values that should be consistently embedded across engineering education. The group agreed that the intention behind this identification process would be to surface broad categories or "bins" of what students need to know and to learn, rather than to specify any exact or prescriptive way to deliver content. The group agreed that a new framework could also be used to engage a broader community of stakeholders on co-development of content, and to create greater momentum and transparency for the efforts.

Participants also spoke compellingly about the need for creating a shared toolbox of vetted resources to support faculty, both for those who are already teaching environmental responsibility in their courses and those for whom the work is more nascent. It was also generally agreed upon that using a systems approach and lens was essential, due to the complexity of the issue. Additionally, participants agreed that a purely consensus-based approach might not serve the collective in the nuanced way that this work requires, or ultimately even be feasible given the range of stakeholders and the many potential pathways to impact. There was an additional brief conversation about the dangers associated with continuing to make investments that could actually strengthen the status quo; questions posed included "What in the current educational process is reinforcing the status quo?" and "How will we ensure that this effort is different?"

Day One closed with a brief discussion of four proposed core questions or "elements" of a framework, generated from themes that came up during the pre-meeting participant interviews:

1. What do all engineering students need to know/learn? What do they need to be exposed to?
2. What do engineers need to be able to do upon graduation?
3. What knowledge, skills, and experiences related to environmental responsibility should be fundamental to all engineering disciplines?
4. What is required to support achievement of the above? (e.g. policy, curriculum redesign, faculty engagement, content, etc.)

Roundtable participants offered initial feedback on these questions as a set-up to guide Day Two discussions. In particular, it was noted that the questions may be redundant with or overlap other existing engineering accreditation guidelines, such as the 2019 ABET criteria for student outcomes[3]. Some participants suggested these redundancies could offer new opportunities for positive change with regard to embedding environmental responsibility in engineering curricula, since higher education institutions will be actively seeking new ways to meet these new ABET criteria.

DAY TWO

Vision and Core Questions

Participants reconvened on Day Two to engage in a structured conversation using a process called The World Café. These conversations took place within a few agreed-upon parameters and boundaries; namely, a focus on undergraduates and engineers for now, as well as on the environmental aspect of sustainability (there was consensus that while the social and economic aspects are equally important and interdependent, environmental responsibility was of primary focus for this roundtable). Additionally, participants agreed that discussions of learning objectives within the context of the World Café would include both curricular and extracurricular elements, and that the desired timeline for reaching target goals would be 2030, to align with the United Nations' 2030 Agenda for Sustainable Development[4].

The first round of facilitated discussions focused on the broad questions "What is it that we want to achieve? What is the 'it'?" and resulted in the identification of three broad, overlapping themes to help define the environmental responsibility landscape:

- Theme One focused on systems thinking and moving beyond physical and/or performance parameters to also include and address environmental issues.
- Theme Two was awareness of what basic knowledge, skills and sets of experiences students need to have in order to be prepared to address those environmental issues. Included in these were a

variety of knowledge/experience bins, as well as examples of tools and pedagogical approaches that could be used to achieve these learnings.

- Theme Three was the ability to understand and appreciate differences and diverse perspectives, in order to address collective opportunities and complex challenges. Participants agreed that it is incumbent upon engineers to recognize the value of working globally and across disciplines—humanities, policy, business, design, etc.—and to know when to supplement their expertise with others' expertise.

Participants surfaced three additional concepts that intersected all three of the above themes:

- the importance of cultivating a sense of moral responsibility and a discrete environmental responsibility value set for all engineering students;
- the idea that all of these efforts must be focused on attainment of clear educational outcomes grounded in environmental responsibility; and
- the belief that there is value in identifying and teaching about leverage points for change, to ensure students have the fullest picture possible of environmental responsibility, both in the context of their own work and with regard to larger systemic and global challenges.

Guided by these newly identified themes, participants engaged in a second round of facilitated dialogue focused on four revised core questions:

1. What do ALL engineers need to be able to do?
2. What educational outcomes (knowledge/skills/values/associations) will enable to us to make progress?
3. What experiences, curricular and extra-curricular, do students need to be exposed to in order to achieve the desired educational outcomes?
4. What systemic changes are needed to make it possible for these curricular and extracurricular experiences to become a reality for ALL engineering students?

Overall, there was a high level of consensus on the phrasing of the first three questions. For question #4, participants offered feedback to tweak the question further in a way that suggested more of a "both-and" approach—i.e. simultaneously considering what systems need to change *and* what grassroots and bottom-up changes can be made. Further efforts to revise these questions should focus on incorporating this recommendation.

Finally, a few additional meta-questions arose from the discussion, and should be considered in the continuance of this work:

- What patterns or behaviors in the system have gotten us to where we are (i.e. a landscape in which the principles of sustainability and the skills needed to implement them have not been integrated into educational preparation for the vast majority of engineering students), and are keeping us where we are?
- What are we [faculty members] currently teaching and doing that's leaving the wrong message with students, either through "errors of omission" (not treating environmental responsibility as a critical constant in coursework) or by neglecting to fully prepare students to address the challenges they will face after graduation?
- What are people [faculty, administrators, industry leaders] worried about, that is stopping them from changing? What do they fear they will lose if the change occurs?
- Who are the winners and losers if change happens?

Roadmap and Stakeholders

Following the World Café discussions, participants worked together on creating a roadmap for action to drive this work forward. The group agreed that they should focus on the near term—the remainder of 2019 – in order to emphasize the urgent window of opportunity in which to create infrastructure needed to effect change. A lively discussion resulted in recommendations across three main areas identified as necessary to make progress: 1) the vision of the effort 2) the people and organizations to involve and 3) the assets needed.

With regard to vision, the group prioritized naming/branding the initiative and clarifying metrics for success, along with a stated timeline for achieving the work. In terms of people, the group named the importance of identifying both the leader(s) of the work as well as additional project teams/stakeholders to be engaged, and a desire for further opportunities to convene sub-teams and stakeholder groups. Recommended assets include the creation of a clear orienting vision, a "living document" that could be continually updated, a repository of environmental responsibility tools, resources and talking points to facilitate communication with other faculty and deans, and some initial mapping of existing curriculum and of the systems that most coincide with ER engineering.

Participants then identified nine critical stakeholder groups needed in order to comprehensively embed the principles of environmental responsibility into engineering curricula: 1) professional associations 2) funders 3) university systems 4) media 5) students 6) government 7) industry 8) faculty and 9) the Earth and other unheard voices (e.g. flora/fauna, climate refugees). Roundtable participants self-organized by stakeholder groups to identify critical influencers and leverage points and developed recommendations for engaging stakeholders in each of these groups towards meaningful change.

Day Two concluded with the expression of commitments, defined as "promises made independent of an expectation of return." Participant commitments included the establishment of new or enhanced collaborations, offers of shared resources from their respective institutions or organizations, and invitations regarding upcoming publication and conference opportunities. The Foundation and VentureWell also offered commitments to continue to work with the participants and other stakeholders in order to further galvanize momentum around environmental responsibility, and to be intentional about ways to weave it into their own current and future programming and strategic priorities. The spirit of collaboration and urgency was palpable as the event closed, with many participants continuing conversations in the meeting space well after official programming concluded.

RECOMMENDATIONS AND NEXT STEPS

By the end of the roundtable, participants were able to achieve a level of initial alignment around a number of key elements needed to advance this initiative. These focus areas are recommended as a starting point; they will benefit from having clearly identified project leader(s) as well as strategic contributions from roundtable participants and other critical stakeholders:

- Develop an initial strategy document or white paper that clarifies the "why/why now" (i.e. philosophy and urgent need for this work), the "what" (initial list of "bins" of student knowledge/experiences and existing tools and resources), and the "how" (vision and high-level roadmap with clarity on stakeholder engagement opportunities).
- Consider developing a systems map in order to more fully understand the current landscape.
- Through coordinated, multi-stakeholder input, set and refine parameters for a framework that clarifies what ER engineering is, and the core questions, goals, and values that define it.
- Develop communication tools, including a project overview, email messages, and scripts to use with key stakeholders in order to solicit their review and feedback, and ultimately to recruit signatories on an updated framework.
- Map existing frameworks and other relevant resources to create an initial repository that can be shared with stakeholders.
- Create a timeline of critical milestones and deliverables for 2019 and for consideration in 2020 and beyond.

EVALUATION AND LEARNINGS

Post-Event Survey

Following the roundtable, participants took a brief survey which assessed the extent to which the goals of the roundtable were met, whether the "right" people participated in the event, what participants planned to do as a result of the roundtable, and who should be engaged in the work moving forward.

Thirteen of the 20 roundtable participants submitted responses to the survey. The majority of respondents agreed that the right participants were present, and many cited specifically that the diversity of thought, knowledge, skills, and abilities among attendees allowed for highly productive conversations that facilitated connection and learning. 85% of respondents reported that the roundtable either met or exceeded their expectations.

> *"The roundtable offered a unique opportunity to meet and cross-pollinate thoughts with other experts in this critical area of knowledge and learning. … So many brilliant and insightful colleagues … I enjoy being challenged by clear and logical arguments from someone who sincerely wants to move toward a shared goal. Such vigorous mental exercise makes us stronger and wiser!"*

Respondents shared a range of feedback in terms of the clarity and achievement of roundtable goals; however, they also acknowledged that accomplishing this work is a long process and provided several concrete suggestions to build on momentum from the roundtable, including the need for a clear roadmap with goals and timelines, and a repository of shared resources.

Additionally, respondents almost unanimously indicated that they fostered or strengthened connections with other roundtable participants and that the roundtable helped them to feel part of a connected community. Finally, they stated they were excited about, and committed to, participating in the next steps of the work; many also recommended names of additional stakeholders to engage moving forward.

Overall, survey findings indicate that the roundtable provided value to attendees and met its desired outcomes—to establish the groundwork for a connected community; to co-create initial, high-level exploratory questions and themes to serve as building blocks for a framework on ER engineering; and to offer preliminary recommendations for a roadmap of next steps for collectively continuing the work. While participants grappled with the challenges and opportunities associated with creating a new framework for ER engineering, discussions ultimately resulted in a series of valuable suggestions and recommendations for carrying the work forward and engaging additional stakeholders towards collective impact.

REFERENCES

1. Mesa, Jaime A & Esparragoza, Ivan & Maury Ramirez, Heriberto. (2017). Sustainability in Engineering Education: A Literature Review of Case Studies and Projects.

2. Faludi, J & Gilbert, C. Teaching Environmentally Responsible Inventing: Higher Education Environmental Landscape Research and Analysis Phase 1 (2018).

3. Criteria for Accrediting Engineering Programs, 2018-2019. Retrieved from https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/#GC3

4. United Nations Sustainable Development Goals Knowledge Platform. (2019). Retrieved from https://sustainabledevelopment.un.org/sdgs

Appendix A:
Principles of Environmentally Responsible Engineering Roundtable
Pre-Meeting Participant Interview Questions

Current Reality

1. Is (sustainability) consideration of environmental impacts important in the context of your work? In what way?
2. Do you believe that engineers have a role to play in addressing some of the most pressing environmental issues we face? Why – why not? What do you see as some of the most pressing issues or problems we face?
3. Do you believe that engineering students are currently receiving the education they need in the area of sustainability and environmental impact? Why do you say this?
4. What do you believe are the essential knowledge, skills and experience that students need to gain in the course of their engineering education in order to be capable of applying environmentally responsible practices in their fields?

Future State - Gaps

5. In considering sustainability and environmental impact, imagine engineers in the future... What is your greatest hope?
6. Are you aware of approaches to sustainability or environmental impact (e.g. within specific engineering disciplines - e.g. environmental engineering) that would help support the future you envision?

Possible Actions

7. What would be needed to move from principles to practices?
8. Do you believe that a core set of environmentally responsible principles for engineering students is needed? Do you think it is doable? Is it an appropriate next step or is there another appropriate next step?
9. What would success look like for the planned roundtable? What do you think your greatest contribution to a positive outcome would be?

General

10. Is there anyone else you would recommend we talk to or invite to the roundtable about this topic and why?
11. Are there any particular sources of information you would recommend we tap into for insight (artifacts, literature, research, etc.)?
12. Is there anything else you would like to add or deem critical to address during our time together?

Appendix B:
Participant Agenda

Principles of Environmentally Responsible Engineering: Creating a Roadmap for Change

Pre-conference Roundtable: VentureWell OPEN 2019
March 27-28, 2019
Renaissance Washington, D.C. Hotel
Meeting Room 5

Wednesday, March 27

1:30pm	**Welcome and Setting the Context** Carol Dahl, Executive Director, The Lemelson Foundation Phil Weilerstein, President, VentureWell Darcy Winslow, President, Founder and Faculty, Academy for Systems Change
1:50pm	**Background and Intention** Cindy Cooper, Program Officer, The Lemelson Foundation
2:05pm	**Desired Meeting Results, Ground Rules** Charles Holmes, Founder and Faculty, Academy for Systems Change
2:15pm	**Introductions**
3:00pm	**Break**
3:15pm	**Invention Education Framework Development** David Coronado, Program Officer, The Lemelson Foundation
3:45pm	**Parallels and Possibilities** Charles Holmes, Founder and Faculty, Academy for Systems Change
4:15pm	**Framework Elements** Charles Holmes and Darcy Winslow, Academy for Systems Change
5:30pm	**Close and Logistics** Charles Holmes and Darcy Winslow, Academy for Systems Change VentureWell
6:30pm	**Dinner** The Salt Line – 79 Potomac Ave SE, Washington, D.C.

Thursday, March 28

8:00am	**Breakfast**
8:30am	**Day One Reflections, Review of Day Two Agenda** Charles Holmes and Darcy Winslow, Academy for Systems Change
9:00am	**Framework Elements Deep Dives (World Café)** Charles Holmes and Darcy Winslow, Academy for Systems Change
10:30am	**Break**
10:45am	**Framework Elements Deep Dives (World Café) – cont'd** Charles Holmes and Darcy Winslow, Academy for Systems Change
12:00pm	**Lunch**
1:00pm	**Roadmap: Stakeholder Identification** Charles Holmes and Darcy Winslow, Academy for Systems Change
1:30pm	**Roadmap: Stakeholder Engagement** Charles Holmes and Darcy Winslow, Academy for Systems Change
3:00pm	**Break**
3:15pm	**Roadmap: Next Steps** Phil Weilerstein, President, VentureWell Laura Sampath, Vice President, Programs, VentureWell
4:00pm	**Individual Commitments** Phil Weilerstein and Laura Sampath, VentureWell
	Closing Rob Schneider, Senior Director of Strategy, The Lemelson Foundation
4:30pm	**Meeting adjourns**

ABOUT THE LEMELSON FOUNDATION

The Lemelson Foundation uses the power of invention to improve lives. Inspired by the belief that invention can solve many of the biggest social and economic challenges of our time, the Foundation helps the next generation of inventors and invention-based businesses to flourish. The Lemelson Foundation sees its role as a convener and collaborator in cultivating a new generation of inventors and problem solvers who view environmental responsibility as a central tenet to the design, manufacturing, distribution and disposal processes for new products and services. Together with a growing community of individuals and organizations, the Foundation is working to ensure all engineers develop the environmental stewardship skills to minimize future harm to the planet.

Established in the early 1990s by prolific inventor Jerome Lemelson and his wife Dorothy, the Foundation continues to be led by the Lemelson family. To date, grants totaling more than $210 million have been made in support of the mission.

For more information, visit www.lemelson.org.

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