Integration of Sustainability Principles in Engineering Education
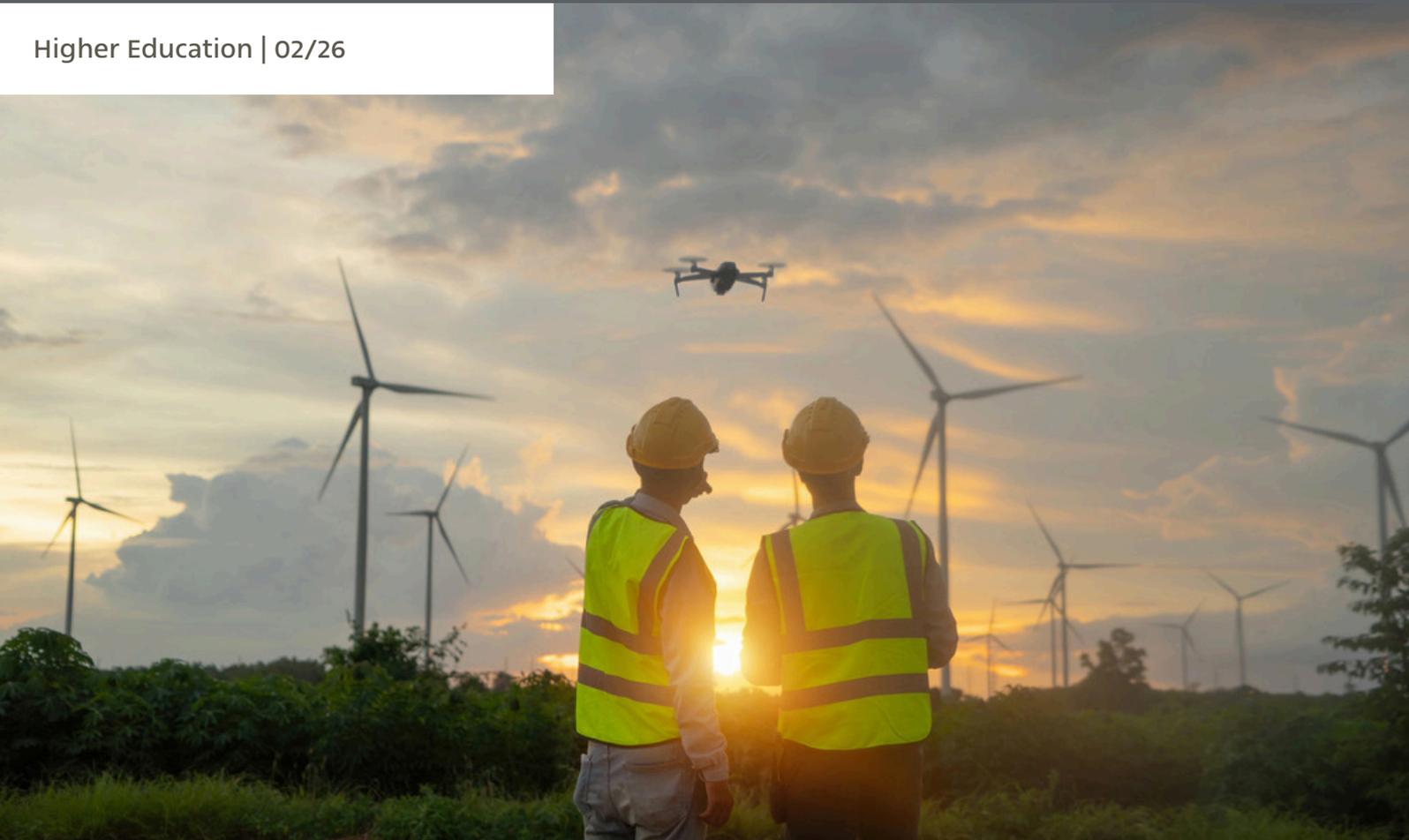
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FOR NATIONAL POLICY RESEARCH

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February, 2026

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Executive Summary

The document addresses the critical need for engineering education to evolve and integrate sustainability and Circular Economy (CE) principles as core competencies. This transition is driven by global changes like climate change, resource depletion, and pollution, and is an integral part of the last wave (sixth) of the innovation waves. characterized by cleantech and AI. Engineers are uniquely positioned to address these 21st-century challenges and contribute to a more sustainable, secure, and healthy world.

Key Areas and Challenges

Education for Sustainable Development (ESD) aims to empower people with the necessary knowledge, skills, values, and attitudes, emphasizing a holistic, interdisciplinary, and socially responsible approach.

However, the field faces significant challenges:

- A major obstacle is a paradigm shift concerning engineering's place relative to science and society, moving away from the traditional "engineering science" focus.

- Other practical challenges include the slow pace of curriculum renewal, faculty struggles to balance technical content with sustainability integration, and staff/management inertia.

- Traditional, strictly mathematical pedagogy is criticized for potentially leading to declining interest.

- A major inhibitor to reform is the focus on research excellence for tenure at research-led institutions, often overshadowing ground-breaking teaching.

- A lack of reliable metrics to assess educational quality beyond traditional methods, particularly for holistic skills and the impact of sustainability education.

Approaches to Integration

Several approaches are being used to integrate sustainability into engineering curricula:

- Adding Dedicated Courses: Introducing one or two courses on sustainability, often as an initial, but not comprehensive, step.

- Integration into Existing Courses: Embedding sustainable development concepts into regular disciplinary courses to make it a core, repeated consideration across the curriculum.

- New Courses/Specializations: Designing new introductory courses or offering specializations (Minors, Certificates, Masters) focusing on sustainability.

- Project-Based Experiential Learning (PBL): Utilizing active learning and project work, often involving teams solving real-world sustainability and circularity challenges.

- Sustainable Development Goals (SDGs) Framework: Using the UN SDGs to structure content and highlight interconnections, which promotes interdisciplinarity.

- Interdisciplinary (incorporating multiple academic fields) and transdisciplinary (connecting with external community stakeholders) approaches to solve complex societal issues.

Facilitators

Facilitators of integration include:

- Industry Collaboration and Internships.

- Non-profit organizations like Engineering for One Planet (EOP) and Engineers Without Borders (EWB), which link engineering and engineering education with societal needs.

- Accreditation bodies (e.g., ABET, Washington Accord) increasingly mandate sustainability requirements.

- Government investment and policy.

- Case studies

- Top institutions illustrate various models:

- University of Toronto (U of T): Offers a "Sustainability Pathways Program" with three tiers: Citizen (extracurricular), Scholar (academic specializations/minors), and Leader (scholar + experiential learning/capstone).

- ETH Zurich: Uses the 17 UN SDGs to guide its sustainability course framework.

- MIT (NEET Program): The New Engineering Education Transformation is a cross-departmental, project-centric initiative with five core areas ("threads," e.g., Renewable Energy Machines, Living Machines) and emphasizes a set of "Ways of Thinking" (e.g., Creative Thinking, Systems Thinking, Humanistic Thinking).

The future of engineering education is seen as integrated, student-centered, and globally-oriented, prioritizing societal needs and environmental sustainability through multidisciplinary and outward-facing curricula.

List of Abbreviations

AAU	Aalborg University
ABET	Accreditation Board for Engineering and Technology
AI	Artificial Intelligence
CE	Circular Economy
ENAEE	European Network for Accreditation of Engineering Education
EOP	Engineering for One Planet
ESD	Education for Sustainable Development
ESW	Engineers for a Sustainable World
EWB	Engineers Without Borders
FAS	Faculty of Arts & Science
GCSP	Grand Challenges Scholars Program
GEL	Gordon Engineering Leadership
IDSS	Institute for Data, Systems and Society
MIT	Massachusetts Institute of Technology
NAE	National Academy of Engineering
NEET	New Engineering Education Transformation
PBL	Project-Based and Experiential Learning
QS	Quacquarelli Symonds
SDG	Sustainable Development Goals
STEM	Science, Technology, Engineering, Mathematics
SUTD	Singapore University of Technology and Design
UCL	University College London
UNESCO	United Nations Educational, Scientific and Cultural Organization

1. The Need

Transition according to what may be termed the "sixth wave of innovation" (figure 1)[1] characterized as the age of AI, robotics and cleantech, involves a substantial degree blurring and convergence between technologies and sectors. [1] The clean tech wave is characterized by emphasis on sustainability, transition to renewable energy sources, clean technologies and circular economy (CE) just to name a few.

Figure 1. Six Wave of Innovation[2]
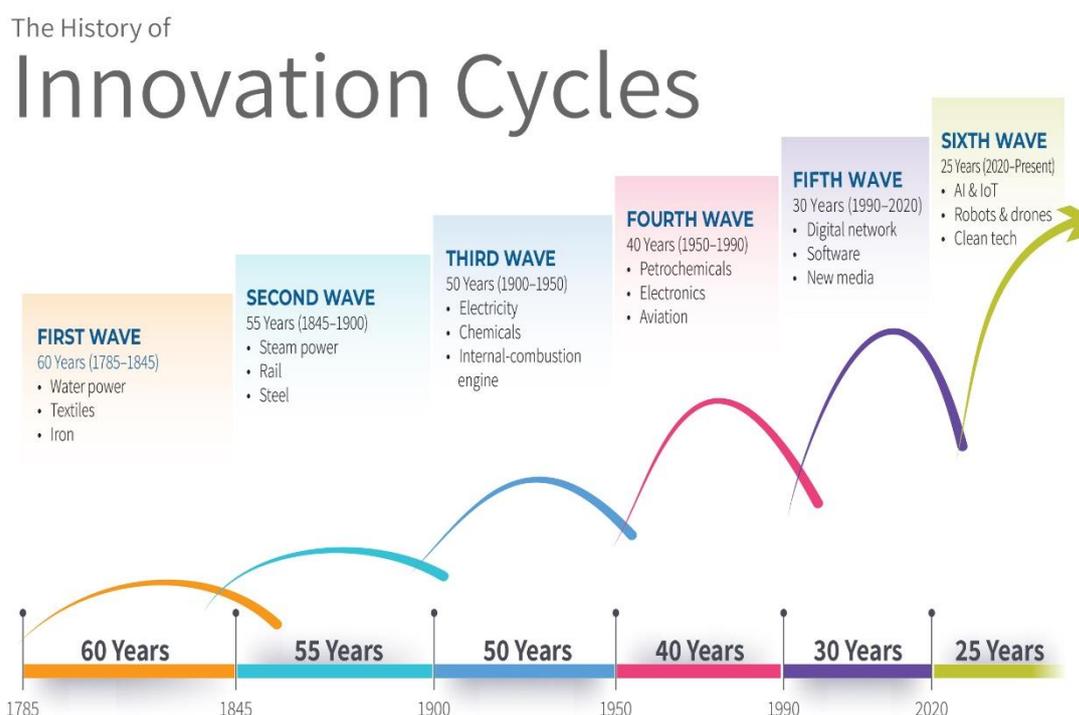
There is a growing recognition of engineers' crucial role in addressing this transition. Global changes include climate change, resource depletion, environment pollution and destruction, poverty and societal changes. Adoption of circular economy and sustainable development principles is thought to be the way to mitigate the detrimental effects these changes may bring. This emphasizes the need for engineering education to evolve beyond traditional technical skills to include a holistic, interdisciplinary, and socially responsible approach, integrating sustainability and circular economy as core competencies.

Moreover, UNESCO has defined Education for Sustainable Development (ESD) [2] as an urgent challenge towards sustainable existence. The National Academy of Engineering

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[1] Technology long Waves: The History of Innovation Cycles. https://digitalrosh.com/knowledge/digital-culture/history-of-digital/technologylong-waves-the-history-of-innovation-cycles

[2] Courtesy of Sigalit Biksenshpan. sigalit.biks@gmail.com

(NAE) of the US has defined the goal of engineering for the 21st century as "continuation of life on the planet, making our world more sustainable, secure, healthy and joyful". NAE also presented 14 goals that must be satisfied globally to realize this vision, named the grand challenges for engineering. From the need to develop affordable clean energy solutions and increase access to renewable environmental resources, up to facing new challenges in health care, challenges potentially impact the quality of all our lives[3].

Education for Sustainable Development is meant to empower people with the knowledge, skills, values, attitudes and behaviors to live in a way that is good for the environment, economy, and society. It encourages people to make smart, responsible choices that help create a better future for everyone.

There is a strong consensus that engineers are uniquely positioned to address the complex environmental, social, and economic challenges of the 21st century. Higher education is identified as playing an important role in furthering the sustainability agenda. The goal is to train engineers who are "prepared, engaged, and empowered to confront the environmental, social, and economic challenges of the 21st century" [3]. Naturally engineering is one of the most important activities in the context of climate change mitigation and adaptation. Therefore, a major area of need and growth for engineering is in the area of sustainable or green engineering taking considerations of what is now termed circular economy (CE). [4]   It is vital to promote the relevance of engineering to address present-day concerns and help link engineering with society in the context of related ethical issues, sustainable development and poverty reduction. The tasks facing 21st-century engineers may be stated as engineering the world to prevent an environmental crisis caused in part by earlier generations, a definition that in engulfed in the definition of the UN sustainability "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [5]. This requires the engineers to "synthesize solutions and not simply to analyze problems", through an approach which is beyond just adding components to an engineering curriculum, [3] but embedding sustainability issues as core elements.

It is believed by education professionals that the future of engineering education needs to be integrated, student-centered, and globally oriented, prioritizing societal needs and environmental sustainability. The trend is towards "student-centered learning to large student cohorts through a blend of off-campus personalized online learning and on-campus hands-on experiential learning" [6]. Curricula will increasingly emphasize "solving human challenges and the problems facing society". Future engineering programs are expected to offer "multidisciplinary curricula that expose students to a breadth of experiences" outside

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[3] Arizona State University School of Engineering, "About GCSP," [Online]. Available:
https://gcsp.engineering.asu.edu/about/.

traditional engineering disciplines [7]. The ultimate goal is to move towards socially-relevant and outward-facing curricula that emphasize student choice, multidisciplinary learning, societal impact, and a breadth of experiences beyond the traditional classroom setting. Key challenges in engineering education include curriculum reform and developing appropriate metrics for the new educational models.

2. Challenges Facing Engineering Education

Some significant challenges exist in engineering education in the course of adapting to meet the demands of a sustainable future governed by CE models. A major obstacle involves a paradigm shift in relation to the place engineering has vis-à-vis science and society. Former MIT president, Chuck Vest, who also served as the US National Academy of Engineering President has said that much of what is considered as engineering fundamentals is shaped by what might be termed as "engineering science" since scientists have come to be the practical inventors. Thus, engineering has drifted too far from practical engineering, and a better disaggregation between science and engineering fields is needed for engineers in order to conceive, design implement and operate complex engineering systems [6]. The other gap is the actual acknowledgement of the urgency for engineering education to adopt sustainable design principles and ideas before actual implementation. For this change preliminary fundamental acceptance by society at large and educational institutions values specifically, is a prerequisite, as nicely suggested by the phrase "culture eats strategy for breakfast" (Peter Drucker).

Other more practical challenges exist in engineering education in the course of adapting to meet the demands of a sustainable future.

- The pace of traditional curriculum renewal may not be sufficient to keep up with potential market, regulatory and institutional shifts. Engineering faculty often struggle to balance this against the need for increasing technical curriculum content.

- Integrating sustainability faces challenges such as staff and management inertia, with faculties that agree on the goals but seem not to know how to achieve it.

- There's a recognized dissonance between learning objectives and activities, where programs may claim interdisciplinary collaboration but fail to provide cross-faculty experiences. Current leaders in engineering education often have educational excellence confined to "pockets" rather than being multifaceted renaissance scholars. Faculty in general lack pedagogical training, which leads to poorer understanding of student learning outcomes (SLOs), thus diminishing the teachers' ability to address them in their respective courses, and lowering the implementation rate.

- Traditional pedagogy of engineering education, which is usually strictly mathematically based, although necessary, is criticized for leading to a declining interest in engineering at university level and for sustaining a linear step by step model of innovation [1]. New

approaches like problem and activity-based learning and just-in-time and hands-on application approaches[4] are needed to make courses more interesting and relevant. [3]

- A major inhibitor to educational excellence and reform is that most engineering programs are at research-led institutions. Faculty are ultimately being judged on being an excellent researcher and tenure is based on research and not necessarily on innovative ground-breaking teaching.

- The students, on the other hand, may not be inclined to maintain the engagement needed for self-directed exploratory learning style.

- There is a lack of "reliable and robust data relating to educational quality assessment" beyond traditional metrics [1]. There is a call for metrics that capture the 'delta' added to the students during their studies and the benefit to their long-term career trajectory and impact. Developing robust metrics to assess the quality and impact of engineering education, particularly concerning sustainability and holistic skills, is an ongoing challenge.

- Students' choice of sustainability related programs is usually only a minute fraction of the student body. There is a need to "open up" methods of choice without restriction to a specific program which may not appeal to large crowds.

- Almost all countries suffer from an under-representation of women and other gender related issues in engineering. Many countries face a "shortage of engineers" and a declining interest among young people in the profession [1]. This necessitates government action, investment in R&D, and improved public perception of engineering. Efforts on creating inclusive workplaces, addressing biases, and providing supportive measures would help attracting larger crowds to the profession.

3. Issues of Sustainability Integration into Engineering Education

There are several Issues in attempted integration of sustainability and CE to engineering curricula, from the technical aspect of what is the organizational framework for the sustainability content, up to more fundamental issues such as interdisciplinarity/ transdisciplinary content and the relative merits of compulsory versus voluntary sustainability programming.

- **Addition of Dedicated Courses or Modules**

  One common approach, especially in earlier stages, is to add one or two courses specifically dedicated to sustainability or environmental technologies without

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[4] "Just-in-time" learning is a training approach that delivers bite-sized, specific, and relevant information exactly when needed to complete a task. A "hands-on application" is the direct, practical use of skills or knowledge to perform a task, as opposed to passive or theoretical first learning.

significantly altering the existing curriculum. This is often considered an initial step, sometimes characterized as naïve, as it may not lead to a comprehensive integration of sustainability principles into students' professional practice. Examples include early sustainable development courses that were primarily a series of lectures added to an existing program.

- **Integration into Existing Disciplinary Courses**

  A more integrated approach involves embedding the concept of sustainable development into regular disciplinary courses. This aims for sustainability to become an integral part of the entire curriculum, involving as many teachers as possible. The goal is to ensure that sustainability is a core consideration from the very earliest stages of all degree programs and is repeated regularly, rather than being an afterthought.

- **Design of New Elementary Courses and Specializations**

  Some institutions design new elementary courses for all students, providing a general introduction to sustainable development concepts. Another option is to offer the possibility to graduate in a sustainable development specialization within each department. At the undergraduate level, these are often "with" degrees where sustainability is a specialism chosen in later years. At the postgraduate level, there is a wider range of programs with sustainability as a central theme.

- **Project-Based and Experiential Learning**

  The introduction of sustainability topics via project work is an important approach, often hand-in-hand with active learning methods. There is a general agreement on the importance of active learning for increasing student retention. Project-Based Learning (PBL) is increasingly used for environmentally sustainable design (ESD) integration. This involves students working in teams to solve real sustainability and circularity challenges, fostering collaboration and practical skills.

- **Sustainable Development Goals (SDGs) Framework for Teaching Sustainability**

  The comprehensive nature of the SDGs dictates a pedagogical approach which encompasses a broad range of ecological, social, economic, and institutional dimensions of sustainability, and addresses the dynamic interconnections among the different goals.

  However, despite the benefits of framing course content around SDGs, studies have shown that professors have not widely adopted SDG teaching due to a lack of knowledge, resources, and only a few universities have aligned their strategies with the

SDGs [8]. Hybrid approaches which integrate competencies like tools, methods, and skills needed to find actionable solutions for the real-world sustainability problems structured by the SDGs, may help to promote inter-disciplinarity and trans-disciplinarity through the interconnections among the SDGs.

The SDG approach helps highlight areas of focus and connections between all levels of programming from individual courses to entire divisions. Knowledgeable collaborations can be made between disciplines to form new programs and implement sustainability into pre-existing programs. UK's engineering higher education programs for example often connect sustainability teaching to specific UN SDGs, with SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 9 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and communities) and SDG 13 (climate action) being most prevalent. The University of Toronto (U of T) and U of British Columbia have both established sustainability course inventories based on SDG keywords that are found in the course syllabi, with U of T expanding into community- engaged learning and co-curricular and extracurricular learning (see paragraph 5.1).

- **Interdisciplinarity vs. transdisciplinary**

Universities shifting to sustainability learning have emphasized the importance of interdisciplinary and transdisciplinary collaboration. The interdisciplinary approach refers to a pedagogical method that incorporates multiple disciplines of academia to provide students with a greater balance of learning and understanding of social problems. The transdisciplinary approach moves beyond the university, connecting students with community stakeholders to gain a real-world perspective on sustainability issues. Interdisciplinary learning is more engrained in university sustainability programs that are using the SDG approach which allows for multiple departments to work together on issues related to sustainability. Inclusion of transdisciplinary experiences will allow students to build the competencies required for solving real-world problems that cannot be learned in a classroom setting. The complexity of solving today's societal issues demands external stakeholder collaboration and input in order to successfully address these issues in an effective, holistic way [9]. Incorporating both interdisciplinary and transdisciplinary approaches into sustainability programs facilitates learning and collaboration in both formal and informal spaces that supports the integration of SDGs into sustainability programs [2]. The input from a diverse group of faculty members and external stakeholders would not only boost sustainability learning among students, it could address the challenges that some faculty face when teaching within the sustainability space where their knowledge may not be sufficient.

▪ **Mandatory vs voluntary**

Universities have been offering different forms of sustainability programs and courses as a means of integrating sustainability into their curriculum. Often these programs have a common structure. Introductory, mandatory courses that lay the groundwork of sustainability knowledge and competencies that are the basis for future courses followed by elective courses for students to choose how and where they want to complete their credits, often culminating in a "capstone project" that applies the experiences and opportunities students have developed throughout the program to a real-world problem.

Despite the theoretical value of new programs, in practice, many universities lack the resources and students lack the time and space in their course scheduling for new sustainability courses. Therefore, embedding sustainability into pre-existing courses is a popular approach to teach sustainability. While these approaches work well for students choosing to focus on sustainability, offering sustainability programming to the large numbers of students not concentrating on sustainability issues may result in difficulties concerning accessibility and choice. Adding new mandatory courses for the whole student body would be logistically challenging and highly resource intensive. In such cases, offering voluntary, sustainability-focused courses and options as a means to satisfy program or graduation requirements has been found to be popular with students. It also avoids the problem of forcing sustainability into courses or programming where it does not obviously fit. A logical solution may be offering elective courses, however, it was shown that basic major courses on sustainability had better implementation for SLOs compared to elective courses. Time constraints and general disinterest in sustainability as reasons for a lack of student involvement may be alleviated through linking sustainability to career opportunities and integrating sustainability into existing curricula.

4. Facilitators of integration of Sustainability into Engineering Studies

Curricula increasingly emphasize the role, responsibilities, and ethics of engineers in society, with a focus on tackling societal challenges like water scarcity, air pollution, and the shift to non-carbon-based industries. No surprise than that Industry collaboration labs and internships are key practical components in many sustainability-integrated curricula.

Beyond industrial cooperation there are quite a few non-profit organizations which may provide data and insight to such integration.

- Engineers Without Borders (EWB)[5], Engineers for a Sustainable World (ESW)[6], World Federation of Engineering Organizations (WFEO)[7], Engineers Against Poverty[8] and similar groups attract students by connecting engineering with sustainable development and addressing societal needs, leading to curriculum changes where undergraduates learn about sustainability, ethics, and teamwork as part of their degree. They highlight the need for engineers to be engineering zealous who are passionate about their profession and who become role models [1].

- Accreditation bodies, such as ABET (formerly known as the acronym Accreditation Board for Engineering and Technology)[9] and ENAEE (European Network for Accreditation of Engineering Education)[10] are increasingly integrating sustainability requirements into their criteria, providing external motivation for curriculum changes. Strong emphasis by accrediting bodies can significantly impact curriculum development.

- The Washington accord[11] explicitly relate to sustainability, requiring engineers to apply design with considerations of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors and to recognize ethical and professional responsibilities recognizing engineering qualifications globally [3].

- Government Policies: Government investment and policy, such as Singapore's commitment to Singapore University of Technology and Design (SUTD) or Japan's Basic Law on Science and Technology, are crucial for fostering educational reform and promoting engineering disciplines [7]

- Education for Sustainable Development (ESD) is defined by UNESCO as "The process of empowering people with the knowledge, skills, values, attitudes and behaviors to live in a way that is good for the environment, economy, and society. It encourages people to make smart, responsible choices that help create a better future for everyone."

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[5] EWB-Israel: (https://www.ewb-il.org/)

[6] ESW: https://www.eswglobal.org/

[7] WFEO: https://www.wfeo.org/about-us/

[8] Engineers Against Poverty: https://engineersagainstpoverty.org/about/

[9] ABET: https://www.abet.org/about-abet/

[10] ENAEE: https://www.enaee.eu/

[11] https://www.internationalengineeringalliance.org/accords/washington-accord]

5. Higher Education Institutes' Commitment to Sustainability

Using the QS world university ranking[12] on sustainability several top schools' programs were surveyed (institute site) surveying the schools programmatic declaration on ESD. All schools accent their conduct as a sustainable organization in areas as green construction, waste reduction, energy conservation etc.

5.1 University of Toronto (U of T)[13] [9]

U if T has established a "Sustainability Pathways Program" to provide all undergraduate students with the opportunity to incorporate sustainability learning into their program and develop cross-cutting interdisciplinary skills. The program encourages students to become sustainability citizens, scholars, and leaders, or a combination of the above through an integrative tiered framework of co-curricular activities learning.

Sustainability Citizen

The Sustainability citizen program allows students to receive official recognition for their sustainability-related extracurricular activities.

Sustainability Scholar

The sustainability scholar program has been underway across five divisions.

- Faculty of Architecture, Landscape and Design – Certificate in Sustainability of the Built Environment
- Faculty of Applied Science & Engineering – Sustainable Energy Minor and Environmental Engineering Minor; Renewable Resources Engineering Certificate and Electric Vehicle Design Certificate
- Faculty of Arts & Science (FAS) – Certificate in Sustainability

Sustainability Leader

The sustainability leader program is intended for recognition to the students who complete the scholar and citizen programs plus an added experiential learning/capstone activity.

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[12] QS world university ranking[12] is an annual publication of university and business school rankings compiled by the British company **Quacquarelli Symonds (QS)** company, a higher education analytics firm. [16]

[13] https://sustainability.utoronto.ca/teaching-learning/sustainability-pathways-program/

5.2 ETH Zurich[14]

ETH Zurich trains future generation to incorporate aspects of sustainability in their professional lives and empower students to contribute to sustainable development. The framework of sustainability integration in teaching at ETH is guided according to the 17 Sustainable development goals (SDGs) of the United Nations 2030 agenda.

Below is a chart (figure 2), representing the spread of number of courses according to the SDG goals and an example of selection courses that will provide with relevant knowledge, methods and skills to promote sustainability, regardless of the program of student may peruse.

Figure 2. Example of ETH Zurich Sustainability Courses Offered in light of SDG Goals[15]
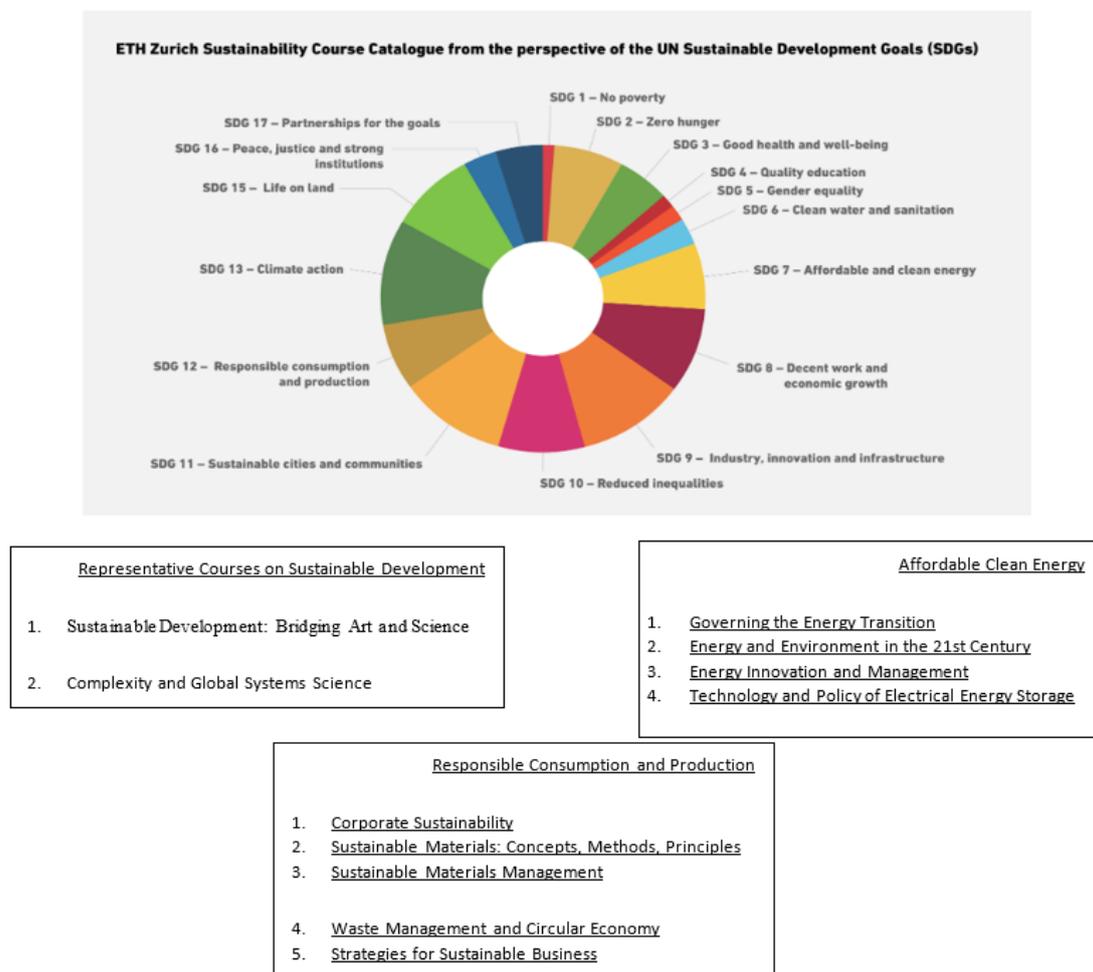
5.3 University College London (UCL)

UCL's strategic direction for sustainability is displayed in the new sustainability plan (2025–2035) that aims for net-zero carbon emissions across by 2040. The strategy focuses on four key areas: climate action, biodiversity, responsible consumption, and education and research. Key initiatives include integrating sustainability across the curriculum, aligning the UCL grand challenges program with learning themes like the climate crisis, and reducing campus emissions to meet ambitious net-zero targets. The goals in sustainability education are:

- Develop and implement an institutional sustainable education plan to integrate sustainability into all teaching and learning.
- Embed sustainability through curriculum design principles and the grand challenges program.
- Build sustainable literacy across formal and informal curricula.

5.4 Aalborg University (AAU; Denmark) [10]

Aalborg university is a leading university in Denmark with a high-ranking engineering program based on Problem Based Learning (PBL) as the core pedagogic approach. Research groups form all faculties and the "UNESCO Center in PBL " is conducting research in engineering education at the Institute for advanced study using PBL which includes areas like digitized learning, education for sustainable development, STEM (Science, Technology, Engineering, Mathematics) education. Engineering student are engaged in interdisciplinary projects, collaborating across semesters, campuses and degree programs. The projects are organized in groups tackling a specific problem often defined by an industrial partner with a specific physical product in mind. The target is to increase students awareness to their own discipline, related subject areas and society grand challenges.

5.5 Massachusetts Institute of Technology (MIT) [6], [11]

MIT deserves a special mention as a top leader in engineering and science education. This is due to the thoughtful consideration and reflection it devotes to "New Engineering Education Transformation" (NEET) program. A cross-departmental, project-centric, education initiative cognizant to the intertwined role of culture and hard-core engineering to rethink engineering education, charted in 2016. NEET graduates will be prepared to work as entrepreneurs/innovators, makers and discoverers, and future leaders with the 21st skills, through learning and practicing the NEET ways of thinking (table 1). The cross departmental

approach did not only involve subject matter engineering departments but also humanistic and extra-departmental service units. Linguistics and philosophy for strengthening personal skills, architecture for creative thinking and the library for self-study as an example. Applying cognitive approaches as creative thinking, critical and analytical thinking, systems thinking, humanistic thinking, and making, that can help individuals think and learn more effectively and efficiently on their own initiative.

NEET has launched 5 areas of operation for integrated engineering (as updated to 2021) [11] ("threads" in NEET terminology).

- **Renewable Energy Machines**

  Design and built devices, systems, or machines that capture energy from natural, replenished sources like the sun, wind, and water to convert it into usable electricity or heat. i.e. solar panels, wind turbines, and hydroelectric dams, which harness these resources to generate power without the high emissions of fossil fuels. i.e. design, simulate, and build energy supply systems with lower CO_2 emissions.

- **Advanced Materials Machines**

  Design, fabricate, and evaluate a high-volume manufacturing process; Additive manufacturing, 3D printing, powder and casting processes, advanced polymer processing approaches—all applied to the aerospace, automotive, energy, and health care sectors;

- **Autonomous Machines and Robotics**

  Development focused on creating machines that can perceive their environment, make decisions, and act independently to achieve a goal. Accomplished through a combination of sensors, artificial intelligence (AI), and machine learning (ML), enabling machines to perform tasks in complex, dynamic environments with minimal or no human intervention. i.e. self-driving cars, industrial robots, drones in agriculture and healthcare assistants.

- **Living Machines**

  Bioengineered systems that use living organisms, like plants and microbes, to perform functions typically done by mechanical or chemical systems. The design to mimic and enhance natural ecological processes to provide sustainable, self-maintaining, and environmentally compatible solutions. i.e. design and build organs on a chip.

- **Digital Cities**

  Integration of technologies (Internet of Things (IoT), artificial intelligence (AI), and cloud computing) to manage large city systems as transportation, energy, and water, while also fostering a digital economy, promoting transparency, and working to bridge the digital divide for inclusivity.

The programs (threads) are all a cooperation of several scientific and engineering departments as needed. A feature which surprised NEET administration was the strong sense of community students found to be highly beneficial for a productive interdisciplinary program. Community was than established as another core feature of the NEET program (figure 3).

Figure 3. Level of Community at MIT NEET program[16]

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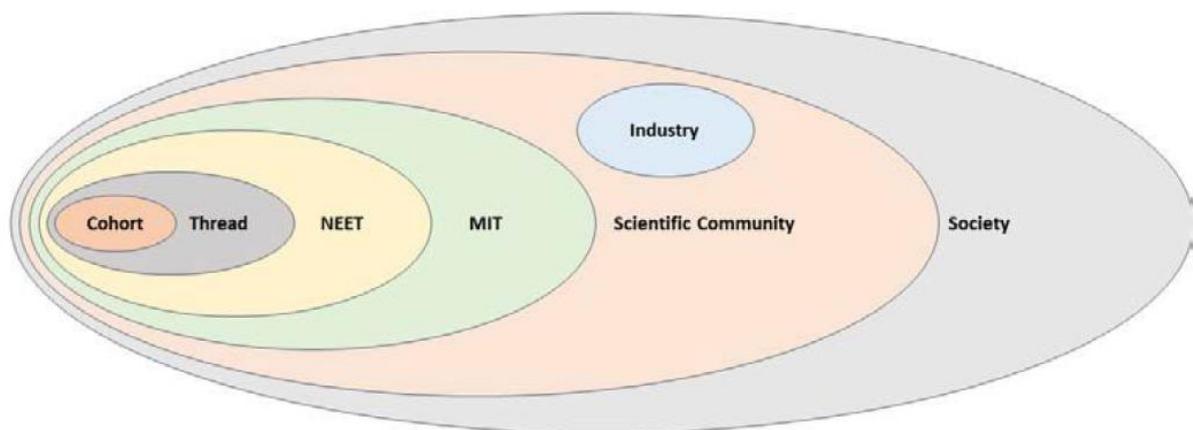
[16] The figure is taken with permission form "Engineering Education Transformation (NEET) program at MIT - Building community, developing projects, and connecting with industry." ASEE Annual Conference and Exposition, Conference Proceedings. https://www.asee.org/public/conferences/140/papers/25447/view

Table 1. MIT ways of thinking of the NEET Program Guiding Modes and skills for Future Engineer

Way of Thinking	Description	MIT Department
Learning how to learn	The motivation and curiosity, reflected in behavioral patterns, to think and learn on one own initiative, throughout lifetime	Libraries
Making	Innovating, by inventing and bringing about artifacts that have never before been in existence: Conceiving (understanding needs and technology, and creating concept), designing, implementing, and operating products and systems that deliver value	School of Engineering — Makerspaces
Discovering	Advancing the knowledge of our society and world by exploring, identifying, and generating new learning, often by conducting research that employs scientific methods and leads to new fundamental discoveries and technologies	School of Science
Interpersonal Skills	Engaging with and understanding others: communicating, listening, dialog and emotional intelligence, working in and leading teams, collaboration and networking, advocacy, and leading change	Sloan School of Management
Personal Skills and Attitudes	Initiative, judgment, and decision making; responsibility and urgency; flexibility and self-confidence; acting ethically and with integrity; social responsibility; dedication to lifelong learning	School of Humanities, Arts & Social Sciences; Gordon Engineering Leadership (GEL) program
Creative Thinking	Forming something new and somehow valuable, for example by focusing thought, incubating new ideas, illuminating them in conscious awareness, and verifying	School of Architecture and Planning
Systems Thinking	Predicting emergence of the whole by examining of inter-related entities in context, in the face of complexity and ambiguity, for homogeneous systems and systems that integrate multiple technologies	Institute for Data, Systems and Society (IDSS)
Critical and Metacognitive Thinking	Assessing the worth or validity of something that exists, by analyzing and evaluating information gathered from observation, experience, or communication	School of Humanities, Arts & Social Sciences

Way of Thinking	Description	MIT Department
Analytical Thinking	Working systematically and logically to break down facts and resolve problems, identify causation, and anticipate results, often by applying theory, modeling, and mathematical analysis	Departments
Computational Thinking	Using computation to understand physical, biological, and social systems by applying the fundamental constructs of computer programming (abstractions, modularity, recursion), data structures, and algorithms	Department of Electrical Engineering and Computer Science
Experimental Thinking	Conducting experiments to obtain data: selecting measurements, determining procedures to validate data, formulating and testing hypotheses	Departments
Humanistic Thinking	Developing and exploiting a broad understanding of human society, its traditions, and institutions: knowledge of human cultures, human systems of thought, the social, political, and economic frameworks of society; and modes of expression in the arts	School of Humanities, Arts & Social Sciences

6. Conclusions

With sustainable development emerging as a pressing topic for universities, many have recognized the roles of HEIs in educating future generations of students in sustainability and providing them with the necessary tools to become agents of change in their communities. While literature shows an increasing emphasis on integrating sustainability, practical implementations and systematic evaluations remain underdeveloped. The integration of sustainability spans from adding new materials on sustainability in an existing module, to a new module on sustainability in an established program up to an entirely new program of study on sustainability [3]. It is believed by education professionals that the future of engineering education needs to be integrated, student-centered, and globally-oriented approaches that prioritize addressing societal needs and environmental sustainability. The trend is towards "student-centered learning to large student cohorts through a blend of off-campus personalized online learning and on-campus hands-on experiential learning". [6] Curricula will increasingly emphasize "solving human challenges and the problems facing society". Future engineering programs are expected to offer "multidisciplinary curricula that expose students to a breadth of experiences" outside traditional engineering disciplines. [7] The ultimate goal is to move towards socially-relevant and outward-facing curricula that emphasize student choice, multidisciplinary learning, societal impact, and a breadth of experiences beyond the traditional classroom setting.

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