

Challenges and Opportunities in Delivering Environmental Engineering Education at the Higher Education Level

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<u>DOI(Digital Object Identifier)</u>	<u>Article Received</u>	<u>Article Accepted</u>	<u>Article Published</u>
https://doi.org/10.5281/zenodo.22980099	21.9.2026	23.9.2026	26.9.2026

ABSTRACT

Environmental engineering has become more and more important to civil engineering in recent years in solving problems like water and wastewater management, air and soil contamination, global climate change, and waste and sustainable infrastructure. With the expansion of environmental engineering into wider subjects like chemistry, biology, ecology, data science, and environmental policy, higher education institutions are forced to accommodate this expanded knowledge base into their programme, credits, and financial framework, which has, for the most part, not changed much (ABET, 2026; Thüerer et al., 2018). The current review of state-of-the-art discusses the main issues concerning the delivery of environmental engineering education in higher education institutions. Such issues include rigidity of curriculum, difficulty to incorporate new topics without undermining the foundation, interdisciplinarity of the field, laboratory, field, and software resources, mismatch between academia and industry needs, dynamic regulatory and technological environment that makes it difficult to keep teaching up-to-date, and lack of specialist expertise of faculty members in higher educational institutes (ABET, 2026; Winberg et al., 2020; Vuoriainen et al., 2025).

Moreover, the review looks at the range of potential opportunities that institutions have to address these pressures, such as digital and blended learning, industry partnership and work-based learning, sustainability and circular economy-based curriculum reform, collaboration across academic departments, and inter-institutional and international collaboration. Virtual laboratories have been shown to offer greater access to hands-on learning, and collaborations with industries can help students make the transition from academia to profession (Potkonjak et al., 2016; Vuoriainen et al., 2025).

Key Words: Curriculum development; Environmental engineering; Higher education; Industry-academia collaboration; Interdisciplinary education; Sustainability

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INTRODUCTION

Environmental Engineering has evolved from being a subset of Civil Engineering that primarily focuses on the provision of safe water and adequate sanitation into an interdisciplinary field covering some of the biggest issues faced by today's society. Treatment of water and wastewater, control of air and soil pollution, waste management, adapting and mitigating climate change, and designing sustainable infrastructure are now among its responsibilities, involving knowledge and expertise in chemistry, biology, ecology, data analysis, economics, and public policy, alongside engineering (ABET, 2026). The current accreditation requirements for programs in Environmental Engineering include incorporating the areas of mathematics, chemistry, geoscience and biology, fluid mechanics, material and energy balances, environmental transport phenomena, laboratory experiences, sustainability, life cycle considerations, and professional practice (ABET, 2026).

The increasing interconnectedness of modern environmental problems and the lack of respect to disciplinary boundaries, as well as the increasing necessity of cooperation between engineers, scientists, policymakers and communities, have led to this development. Education in sustainability engineering also puts emphasis on the importance of broader perspectives and competencies, going beyond technical knowledge (Thürer et al., 2018; Gutierrez-Bucheli, Kidman and Reid, 2022).

The universities and institutions that are charged with providing the next generation of environmental engineers must also be under this pressure. The programme curriculum, which is provided over a certain period of years and credit hours, must integrate the growing list of technical material while ensuring the depth of fundamental material such as fluid mechanics, hydrology and mass transfer. In addition to that, the professional accreditation system increasingly requires that students should be capable of demonstrating their skills in communication, design, professional responsibilities, sustainability, and consideration of social, economic, and environmental aspects along with technical (ABET, 2026).

Employers increasingly require from their employees not only engineering knowledge but also professional and transferable skills. A systematic literature review on the topic of engineering employability demonstrated a mutual dependence of engineering knowledge and professional skills of graduates, which implies that both skills are equally important for solving practical engineering problems (Winberg et al., 2020).

This problem is intensified by the rate of change of environmental regulation, technology, and professional practice. The development of new treatment technologies, remote sensing techniques,

environment-related data analysis and sustainable designs, together with legislative changes, cause curriculum material to become outdated in comparison with practice (ABET, 2026).

Institutions face further obstacles in the form of logistical difficulties, such as the expense of keeping laboratory facilities, field and special equipment, as well as the need to secure a sufficiently varied base of specialist expertise within staff members to meet the needs of a rapidly expanding curriculum. The criteria for environmental engineering programmes include laboratory experience, environmental data analysis, and contemporary engineering tools (ABET, 2026).

Despite the above-mentioned issues, higher education institutions today have the ability to explore a large number of options. Digital and blended learning technologies, increased and structured interaction with the industry, sustainability-driven curriculum redesign, interdisciplinary collaboration and institutional partnership are among the areas which may help achieve greater flexibility, relevance and up-to-date nature of the educational programme (Potkonjak et al., 2016; Thürer et al., 2018; Vuoriainen et al., 2025).

This review aims to provide, generally speaking, an overview of the main challenges of providing environmental engineering education in the context of higher education, and to outline the ways that can be used to tackle them. This paper is intended for programme directors, lecturers, curriculum developers and institutional decision makers interested in the development of civil and environmental engineering education.

METHODOLOGY

This investigation will apply an advanced review methodology in order to consider the issues and opportunities that have arisen as a consequence of providing environmental engineering education within higher education. The review methodology will consider the relevant literature concerning issues pertaining to curriculum design, interdisciplinary approaches, laboratory and digital learning, industrial-academic partnerships, sustainability, technological change and the professional readiness of environmental engineering students. The choice of a review methodology was made as the aim of the research was to collate knowledge in a certain field in order to identify general patterns, problems and opportunities, not to collect primary empirical data.

The relevant literature was selected by searching academic and professional databases for articles including combinations of the following search terms: “environmental engineering education”, “higher education”, “engineering curriculum”, “sustainability education”, “engineering employability”, “industry-academia collaboration”, “virtual laboratories”, “digital learning”,

“circular economy” and “interdisciplinary engineering education”. The priority of selection was given to the literature related to the delivery, design and future of engineering education.

For the purposes of this study, both past and recent literature were considered so as to address both the evolution of education in the field of environmental engineering as well as modern issues that affect the delivery of programmes in this field. Recent literature that addressed such issues as sustainability, digitalization, employability, circular economy principles, and collaboration between higher education and the industry received most consideration, while some of the pioneering works in this area were included due to their theoretical value and significance.

All sources and studies were considered relevant to this work if they contributed to one or more of the themes covered by the review. Studies and sources that were concerned solely with environmental engineering without an aspect of its education or higher education component were given less priority. All the selected studies and literature were then analyzed in terms of the main challenges associated with them and potential opportunities.

Six areas of challenges could be outlined on the basis of the thematic analysis of the reviewed literature: curriculum rigidity and breadth of content; interdisciplinary requirements; resources and infrastructure problems; industry-university gap; pace of change in the field; faculty expertise and development. The identified opportunities were then analyzed in the context of these challenges, focusing on issues such as digital and blended learning, collaboration with industry and work-integrated learning, sustainability-driven curriculum reform, cross-departmental collaboration, and international/institutional cooperation.

As a consequence, the review does not only aim to provide an overview of the available literature but also to highlight the relationships between the identified challenges and potential institutional actions. Such an approach enables to draw conclusions about areas where there might need to be increased flexibility and cooperation in relation to the current teaching of environmental engineering, but at the same time, to recognize that the right response is different for each institutional/national/professional setting.

ENVIRONMENTAL ENGINEERING EDUCATION: THE CHANGING LANDSCAPE

Programmes in environmental engineering at the higher education level can be offered as separate undergraduate/postgraduate degrees or as specializations, electives or modules within broader civil engineering curricula. In both cases, institutions are facing the same challenge of accommodating a growing and increasingly interdisciplinary body of knowledge into programmes that have a limited

total amount of time and credits dedicated (ABET, 2026; Thürer et al., 2018). While past curricula were developed mainly focusing on water supply, water treatment and sanitation engineering, present curricula have to be capable of covering topics of adaptation and mitigation of climate change, circular economy, environmental impact assessment, air and soil quality management, as well as the use of modern technological solutions like remote sensing, geographic information systems, and environmental data analytics. The evolution of educational goals is also evident in the existing criteria of environmental engineering program accreditation that cover sustainability, life cycle approaches, impacts on environment, computational tools and professional practice (ABET, 2026).

The expansion of the scope of studies took place step by step due to changes in legislation, technological developments, and employer needs. The findings of research related to sustainability integration in engineering curricula prove that the inclusion of sustainability into engineering programs usually took place through various curricula models, which raises issues related to consistency, assessment, and coordination within the institution (Thürer et al., 2018). All this has happened within an environment that has seen changes in the expectations set forth by the professional accreditation agencies. The current requirements of accreditation agencies require not only technical proficiency but also other capabilities including communication, professional ethics, environmental and societal issues, and design among others (ABET, 2026). These requirements add more challenges to the existing requirement for covering various technical material.

The above changes are not just limited to changes in curriculum material but also in modes of delivery through blended learning and online delivery. There is evidence in literature on the benefits of virtual laboratories in facilitating science and engineering education as a way of alternative or complementary hands-on learning (Potkonjak et al., 2016).

Likewise, the student population has become diverse, and there is increasing interest in careers that are related to sustainability and climate. According to research done on sustainability education, there is a growing expectation that engineering courses need to prepare learners to appreciate the environmental, social and economic aspects of the profession (Gutierrez-Bucheli, Kidman and Reid, 2022).

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Likewise, the student population has become diverse, and there is increasing interest in careers that are related to sustainability and climate. According to research done on sustainability education, there is a growing expectation that engineering courses need to prepare learners to appreciate the environmental, social and economic aspects of the profession (Gutierrez-Bucheli, Kidman and Reid, 2022). This situation is compounded by the sequential nature of engineering programmes whereby basic disciplines form an early part of the curriculum that serve as prerequisites to advanced knowledge. As such, existing accreditation standards still emphasise the importance of foundational mathematics, chemistry, biology, earth sciences, fluid mechanics and environmental engineering principles, hence showing that new content does not necessarily mean replacement of basic technical training (ABET, 2026).

Another challenge associated with this aspect stems from the rate of formal curriculum revision. Accreditation requires continuous improvement, but the process of getting a curriculum approved institutionally could be time-consuming. In this regard, keeping a curriculum relevant necessitates the existence of systems that help ensure that changes in practice do not disrupt curricular cohesion (ABET, 2026).

These constraints lead to a curriculum that becomes too broad or overly focused on existing technical content. The same challenges are seen in reviews of sustainability education within engineering whereby the integration of curricular change becomes a problem rather than adding sustainability topics independently (Thürer et al., 2018; Gutierrez-Bucheli, Kidman and Reid, 2022).

INTERDISCIPLINARY DEMANDS

Environmental engineering issues are inherently interdisciplinary in nature. In the case of wastewater treatment, for example, one may need to consider aspects such as chemical process engineering, microbial treatment technologies, ecology and regulation. Modern environmental engineering accreditation, accordingly, includes mathematics, chemistry, biology, geology, hydrodynamics and environmental systems (ABET, 2026).

In order to educate students adequately for operating in this environment, it is necessary to provide teaching that consciously draws on disciplines such as chemistry, biology, ecology, environmental

economics and environmental politics alongside engineering. Sustainability education scholarship also finds interdisciplinary and intercultural learning crucial yet challenging components of integrated sustainability education (Gutierrez-Bucheli, Kidman and Reid, 2022).

Such an approach to education can prove awkward within an organisational environment characterised by departmental divisions according to disciplines. Developing interdisciplinary curricula can entail coordination among different departments and sharing of teaching duties. Studies on sustainability integration suggest that this may prove administratively demanding (Gutierrez-Bucheli, Kidman and Reid, 2022).

RESOURCE AND INFRASTRUCTURE CONSTRAINTS

Laboratory-based learning, fieldwork, and access to modelling and computation software are key aspects of environmental engineering education. The requirements of the current accreditation scheme include laboratory work and analysis of environmental data in all major branches of environmental engineering (ABET, 2026).

This requirement will need continuous funding for the purchase of equipment and chemicals, technical personnel and maintenance of facilities. There are different levels of abilities among educational institutions to be able to provide such funding, which leads to unequal access to modern learning technologies among students.

Fieldwork requires transportation, supervision, and health and safety precautions. If there are limitations, institutions might lower the scope of practical work or replace practical classes with simulated and virtual learning. Virtual laboratories have been researched as an opportunity for supplementary learning in cases where there is less access to laboratory classes (Potkonjak et al., 2016).

INDUSTRY–ACADEMIA GAP

One issue that regularly crops up in engineering education is the connection between preparation in school and professional practice. According to a systematic review conducted on engineering employability, engineering knowledge and professional skills must be built simultaneously for the graduates to be able to tackle real-life challenges and work in a professional environment (Winberg et al., 2020).

It can be linked to insufficient exposure to live projects, regulatory issues, professional documentation and multidisciplinary teams. Cooperation between industry and higher education institutions may

help bridge the gap in terms of solving problems, developing products and making the transition from studying to professional activities (Vuoriainen et al., 2025).

The gap is further widened due to the disparity between the rate of development of industry practice and curriculum structures. The practice and technology of industries can outpace curriculum structures. Continuous cooperation between employers and universities can be a mechanism to make sure that programme content is relevant to professional needs (Vuoriainen et al., 2025).

KEEPING PACE WITH REGULATION AND TECHNOLOGY

As new science emerges and as environmental priorities and policies shift, there will be changes in environmental regulations. This means that environmental engineering programs should be able to train its graduates to practice in a dynamic regulatory and technological environment. The current requirements for accreditation include aspects of professional practice and the roles and responsibilities of the private and public sectors in environmental protection and regulation (ABET, 2026).

The emergence of new technologies such as computing tools, environmental monitoring systems and advanced treatment systems have also brought changes to professional practice. The current accreditation criteria of environmental engineering program include computing tools, among others (ABET, 2026).

However, curriculum revision is often not as rapid as technological change. A more adaptable curriculum enhancement strategy which includes continuous improvement can overcome this structural lag problem.

STAFF EXPERTISE AND CONTINUING DEVELOPMENT

The wide scope of modern environmental engineering makes it difficult for the academics themselves to have specializations in all the relevant fields. The field includes environmental chemistry, biology, fluid mechanics, treatment technologies, environmental systems, sustainability, data analysis and professional practice (ABET, 2026).

Thus, colleges and universities will need to rely on outside experts, adjunct professors, and people from other departments. Such a combination of efforts will allow introducing new professional knowledge but also requires proper coordination.

Therefore, continuous professional development becomes crucial for keeping the skills of the academic staff updated. Moreover, the accreditation process pays particular attention to the

importance of the presence of appropriately qualified faculty, especially in design-oriented courses in environmental engineering education (ABET, 2026).

- Opportunities for Development
- Digital and Blended Learning

Simulation programs, virtual laboratories and remote-sensing datasets give the opportunity to expand the existing physical laboratory facilities. The virtual laboratory will provide the students with the access to simulated laboratory environments as additional to traditional practical training (Potkonjak et al., 2016).

Blended learning can also provide more flexibility for the students who balance work and studies. However, digital instruction should be viewed as an additional to, but not as a replacement for, physical laboratory and.

Industry Partnerships and Work-Integrated Learning

In order to bridge this gap, structured placements, live briefs by industry partners and industry-funded capstone design could be beneficial. From literature, it is evident that cooperation between higher education institutions and industries can aid in developing practical experience and learning outcomes and also help in transitioning into the professional world (Vuoriainen et al., 2025).

Working more closely with industry partners can also allow programme teams to have knowledge about new skills and professional needs. In any case, for successful collaboration, constant institutional commitment and continuity of efforts are needed (Vuoriainen et al., 2025).

Sustainability-Led Curriculum Reform

Curricula designed according to sustainability and circular economy considerations provide institutions with the opportunity to introduce emerging subjects in a more coherent manner. There has been systematic research which reveals sustainability integration to be an important yet challenging area of engineering curriculum development (Thürer et al., 2018).

Circular economy education has become more relevant since future engineers are expected to take care of resource efficiency, waste minimisation, life cycle considerations and resource recovery. Research on circular economy education has revealed the importance of strengthening the integration of circular economy education in engineering curricula (Mesa and Esparragoza, 2021).

Sustainability as an organisational framework instead of an isolated subject can provide linkages among technical, environmental and policy subjects. Nevertheless, sustainability integration involves

institutional capacity and coordination and cannot be achieved by simply introducing certain subjects to the existing curricula (Gutierrez-Bucheli, Kidman and Reid, 2022).

Interdisciplinary and Cross-Departmental Collaboration

The collaborative efforts between departments such as engineering, sciences, and policy that include joint teaching of courses, research mentoring, and curricular planning may spread knowledge throughout the institution. The interdisciplinary perspective becomes especially important for the field of engineering education in sustainability due to the presence of both scientific, social and economic elements to the problems of environment (Thürer et al., 2018; Gutierrez-Bucheli, Kidman and Reid, 2022).

It also gives students the opportunity to learn more than just from the engineering point of view.

International and Institutional Collaboration

Institutional collaborations, including faculty and student exchange programs and joint learning resources, can facilitate access to specialist knowledge and facilities. International cooperation may also give students an experience of varying environments, technologies, regulations and policies.

The wider literature on engineering education suggests that international cooperation and collaboration may help develop more holistic learning strategies (Thürer et al., 2018; Vuoriainen et al., 2025).

RESEARCH GAP

There is significant literature in the area, examining separate elements of engineering education, such as sustainability in engineering education, employability in engineering education, virtual labs in engineering education, engineering curriculum design, etc. Nevertheless, in most cases, all of these elements are not viewed in relation to each other. This highlights the necessity for a holistic view on how the curriculum design, interdisciplinarity, physical infrastructure, professional competences, technology, and sustainability together affect the provision of environmental engineering education programs in the higher education setting.

Another gap is the connection between the growing scope of environmental engineering and its institutional provision. While previous works highlight the importance of sustainability, interdisciplinarity, technology and the involvement of industry in teaching, there is a lack of literature on how to incorporate all these aspects in programs limited by time, credits, money and faculty capacity. Hence, it is necessary not only to ask what new subjects or technologies are needed to

introduce into the program but also how they could be incorporated without loss of traditional knowledge and skills in engineering.

The other gap in literature concerns the need to pay more attention to the changes in the relation between higher education and practice. While the issue of employability and cooperation of universities and industry have been thoroughly researched, there is a lack of research on the implications of such rapidly developing areas as technologies, regulation, sustainability and data analysis for environmental engineering curricula. Moreover, another gap exists in the lack of consolidation of these topics under one review dedicated explicitly to the problem of providing environmental engineering education. Most literature on the topic covers general engineering education or looks at particular topics such as sustainability or digital education. Therefore, an up-to-date analysis of the existing literature that consolidates the various topics will allow understanding better the structural problems of providing environmental engineering education and the possible options available to organizations.

Thus, in order to fill in the identified gap, this review will consolidate the key challenges and opportunities presented throughout the literature along with their interrelationship. The following will be considered the need for flexible curricula, interdisciplinary approaches, engagement with industry, proper digital and lab infrastructure, ongoing professional development, and sustainability-oriented educational programs.

DISCUSSION

These problems mentioned above are, in large part, structural problems, concerning curriculum development, resourcing, institutional structure and the relation between higher education and professional practice. The rigidity of curricula, resource limitations, the divide between industry and academia, and maintaining relevancy in curriculum are not typically problems that can be solved on an individual level by the educators themselves (Thürer et al., 2018; Vuoriainen et al., 2025).

This is significant because it means that solutions to the issues at hand are not likely to be found in making small changes but rather in changing the underlying structure of the institutions themselves. Current accrediting structures likewise emphasize continuous improvement as a systemic problem and aligning with the program educational objectives (ABET, 2026). However, many of the potential solutions discussed above would not work without an institutional commitment, not an individual one. Digital infrastructure development, partnerships between the industry and the educational institution, collaboration within the departmental structure – all these measures require an institutional decision and effort. For instance, virtual labs would expand practical education opportunities, while

partnerships with the industry could enhance professional training (Potkonjak et al., 2016; Vuoriainen et al., 2025).

If the institution demonstrates the needed commitment, potential opportunities could help to address more than one challenge at once. For instance, the sustainability-based curriculum transformation could become the basis for incorporating new technical content and promoting interdisciplinary learning (Thürer et al., 2018; Gutierrez-Bucheli, Kidman and Reid, 2022).

It is hardly possible to have a single approach to curriculum reform. The diversity of institutional resources, differences between student populations, institutional purposes, national policies and regulations require adjustments.

However, according to the literature, there is clear progress towards more integrated sustainability education, enhanced professional participation and flexibility in engineering education (Thürer et al., 2018; Gutierrez-Bucheli, Kidman and Reid, 2022; Vuoriainen et al., 2025).

What appears consistent in all of the possibilities mentioned above is that there is a shift from fixed and isolated discipline curricula to flexible and sustainable programme curricula which can adapt to change.

CONCLUSION

Environmental engineering education at the higher education level requires reconciling the increasing and interdisciplinary scope of knowledge with limitations of the curriculum design, availability of resources and expertise of the staff members. The current accreditation criteria reveal the wide range of knowledge needed by environmental engineers, including science fundamentals, engineering problem-solving, laboratory work, sustainability, life cycle thinking, computer applications and professional practice (ABET, 2026). The above-mentioned review shows that issues related to curriculum inflexibility, interdisciplinarity, scarcity of resources and infrastructure, gap between the industry and academia, pace of changes in the regulatory framework and technological progress, and lack of sufficient skills among the teaching staff are some of the key challenges for the programme providers. Opportunities include digital and blended learning, strategic partnerships with industry, work-integrated learning, curriculum innovation based on sustainability and cross-departmental and international cooperation (Potkonjak et al., 2016; Thürer et al., 2018; Vuoriainen et al., 2025).

None of the opportunities mentioned above provides for an absolute and universal solution in itself. Nevertheless, all of them require the institutions' involvement and investment along with a proper decision-making process. Together, however, these opportunities indicate the direction to a

curriculum that is more flexible in terms of structure and closely linked to the industry and other disciplines through the concept of sustainability and other principles (Gutierrez-Bucheli, Kidman and Reid, 2022; Mesa and Esparragoza, 2021).

Further efforts in these directions will probably be required for programme providers to prepare students who can deal with environmental challenges faced by civil and environmental engineers.

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