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Reimagining Dental Education for Planetary Health, One Health, and Environmental Sustainability: A Narrative Review With Case Studies

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ABSTRACT

Oral health is shaped by environmental, social, and systemic determinants that extend well beyond clinical care. As frequent points of contact within the health system, oral health professionals are uniquely positioned to advance sustainable practices and holistic health policies. Yet without targeted education, this potential remains underutilized. The growing impacts of climate change, environmental degradation, emerging infections, and non-communicable diseases underscore the need for transdisciplinary learning that recognizes the interdependence of human, animal, and planetary well-being. Planetary Health (PH) and One Health (OH) offer complementary frameworks to address these relationships, while environmental sustainability (ES) provides a practical pathway for safeguarding natural resources and long-term well-being. Aligning dental education with the United Nations Sustainable Development Goals can further promote systems thinking, environmental responsibility, and preparation of future professionals for a more sustainable and equitable future. Together, these complementary approaches support the broader evolution of dental education and practice in response to escalating global challenges. This narrative review describes strategies and resources for integrating PH, OH, and ES into dental education and highlights initiatives at two dental institutions in the United States and the United Kingdom that have made substantial progress in developing formal curricula on these emerging topics.

1 | Introduction

The convergence of shifting and unpredictable weather patterns, environmental degradation, emerging infectious diseases, and non-communicable disease epidemics has highlighted the need for trans- and interdisciplinary learning that recognizes the inseparable relationship between human and animal health, and the health of our planet [1]. The concepts of Planetary Health (PH) and One Health (OH) have emerged as critical frameworks to understand and address these complex interdependencies [1, 2]. PH is a scientific and policy-oriented field that examines how global environmental changes (climate, biodiversity, pollution, and land use) affect human health and well-being [1, 2]. It encourages a systems-thinking mindset that connects environmental degradation with long-term human health outcomes [3]. Within this broader context, OH serves as a complementary, integrative, and transdisciplinary approach that highlights the interconnected health of humans, animals, and the environ-

Faizan Alawi, Jonathan Dixon and Nicolas Martin contributed equally to this work.

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ment, and includes the participation of stakeholders outside of academia [1–3]. OH provides a clinical and ecological understanding of disease and emphasizes trans- and interdisciplinary collaboration across sectors and between disciplines including dentistry, medicine, veterinary science, ecology, public health, industry, and governmental and global agencies [1–3].

Integrating oral health into PH and OH frameworks is essential to advancing a more holistic understanding of how biological, environmental, social, and ecological factors influence overall health and well-being [3–6]. Environmental sustainability (ES), which is the responsible stewardship of natural resources to safeguard the well-being of both present and future generations, is an important operational pathway to reach the aspirational vision of thriving human and animal life on a stable planet (Figure 1) [4, 6]. Together, these complementary frameworks provide a foundation for an essential reimagining of oral healthcare education and practice in the face of escalating social, economic, and environmental challenges.

There is growing recognition of the interconnected role of oral health in the development and manifestation of systemic conditions, including obesity, diabetes, cardiovascular disease, neurodegenerative diseases, and others [7–10]. Dentists are well-positioned to play a crucial role in the early detection of zoonotic and vector-borne diseases that present with oral signs and symptoms [3]. A further example is the need for dentists to take a lead on antimicrobial stewardship to combat the threat of antibiotic resistance, as the profession is responsible for an estimated 10% of global antibiotic prescriptions [11]. In addition, oral health is both directly and indirectly shaped by environmental, social, and systemic determinants that may influence health disparities [4]. In this context, it is relevant to note that increased temperatures, extreme weather, and water scarcity can potentially influence oral hygiene practices, which could lead to adverse health outcomes, particularly among vulnerable populations [12, 13]. Thus, dentists and dental auxiliaries, often considered gatekeepers of health through their regular patient interactions [14], are uniquely positioned to advocate for environmentally sustainable practices and holistic health policies. However, without the required heightened level of awareness, the dental profession's potential to contribute meaningfully to these broader health initiatives remains untapped.

Escalating environmental challenges combined with rapid social and technological transformations are reshaping patient behaviors, values, and expectations; dental education must keep pace [2–6]. Yet despite growing attention to PH, OH, and ES in medical and public health education, the integration of these topics in dental curricula has been limited [15–18]. Dental curricula often remain densely packed with traditional biomedical content, leaving little room for cross-disciplinary reflection [16, 17]. Faculty may also lack expertise in environmental science or global health, leaving them ill-equipped to teach these topics. Institutional inertia is further compounded by a general absence of urgency to address these ongoing challenges [16, 17].

Overcoming these challenges requires faculty champions and institutional leadership. This narrative review describes strategies and resources for integrating PH, OH, and ES into dental education and highlights initiatives at two dental institutions in the United States and the United Kingdom that have made substantial progress in developing formal curricula on these emerging topics. Relevant literature was identified through targeted searches of PubMed/MEDLINE, Scopus, Web of Science, Global Health (CABI Digital Library), ERIC (Education Resources Information Center), and CINAHL (Cumulative Index to Nursing and Allied Health Literature) using an array of search terms (see Supporting Information), and supplemented by reference list screening and institutional resources. Sources were selected based on their relevance to PH, OH, ES, and dental education. The alignment of dental education with the United Nations Sustainable Development Goals (SDGs) [19] is also examined as a means of fostering holistic thinking and environmental responsibility among future professionals. The SDGs include seventeen global goals adopted by all United Nations Member States in 2015 under the 2030 Agenda for Sustainable Development (Table 1) [19]. The SDGs are closely aligned with PH, OH, and ES as they reflect integrated frameworks that address the interconnected drivers of health, ES, and social equity [20].

2 | Framing Planetary Health, One Health, and Environmental Sustainability Within the Curriculum

2.1 | The Informal Curriculum

The informal curriculum encompasses the learning that occurs outside formally structured courses and assessments through interactions, mentorship, extracurricular activities, peer engagement, and experiential opportunities that shape students' knowledge, attitudes, values, and professional identity [21]. Practical approaches to incorporate PH, OH, and ES into the informal dental curriculum may include:

a. Interprofessional engagement to create opportunities for dental students to learn alongside and interact with students and professionals in medicine, veterinary medicine, nursing, public health, environmental science, and policy.

b. Institutional partnerships with community organizations, public health agencies, professional associations, and sustainability offices to expose students to real-world applications of PH, OH, and ES.

cIncorporation of sustainable clinical practices using routine patient-care experiences to model responsible procurement, effective waste segregation, energy and water conservation, environmentally preferable materials, and appropriate prescribing.

d. Community and service-learning experiences to engage students in extracurricular programs and seminars addressing health inequities, climate-related health risks, infection prevention, antimicrobial stewardship, and access to oral healthcare.

e. Providing institutional support for student-led activities including sustainability clubs, advocacy initiatives, and research projects.

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TABLE 1 | United Nations 17 SDGs with potential topics within dental education and practice to address each SDG.

SDG	Goal	What SDG entails	Potential relevance for dental education
1	**No Poverty**	End poverty in all its forms everywhere. Focuses on social protection, access to resources, and basic services.	Train students to offer low-cost or free dental care to underserved populations. Promote outreach programs in impoverished communities.
2	**Zero Hunger**	End hunger, achieve food security, improve nutrition, and promote sustainable agriculture.	Educate on the role of nutrition in oral health. Address malnutrition-related oral conditions, particularly in children.
3	**Good Health and Well-being**	Ensure healthy lives and promote well-being for all at all ages.	Integrate oral health into general health education. Emphasize preventive dentistry and holistic care.
4	**Quality Education**	Ensure inclusive and equitable quality education and promote lifelong learning.	Promote oral health literacy and train students in community education. Encourage ongoing professional development.
5	**Gender Equality**	Achieve gender equality and empower all women and girls.	Ensure equal access and support for women in dental education. Address gender biases in healthcare delivery.
6	**Clean Water and Sanitation**	Ensure availability and sustainable management of water and sanitation for all.	Teach the role of clean water in preventing oral diseases. Advocate for fluoride in public water systems.
7	**Affordable and Clean Energy**	Ensure access to affordable, reliable, sustainable, and modern energy for all.	Encourage energy-efficient practices in dental clinics. Raise awareness of sustainable equipment use.
8	**Decent Work and Economic Growth**	Promote sustained, inclusive, and sustainable economic growth, full and productive employment.	Prepare students for ethical, sustainable dental practice. Support job creation through public oral health services.
9	**Industry, Innovation and Infrastructure**	Build resilient infrastructure, promote inclusive and sustainable industrialization.	Integrate digital dentistry and innovative technologies in curricula. Promote tele-dentistry access.
10	**Reduced Inequalities**	Reduce inequality within and among countries.	Train students to serve diverse, marginalized communities. Promote culturally competent care.
11	**Sustainable Cities and Communities**	Make cities inclusive, safe, resilient, and sustainable.	Encourage urban dental clinics to prioritize accessibility and environmental sustainability.
12	**Responsible Consumption and Production**	Ensure sustainable consumption and production patterns.	Educate on eco-friendly dental materials and waste reduction. Promote sustainable clinic management.
13	**Climate Action**	Take urgent action to combat climate change and its impacts.	Reduce carbon footprint of dental practices. Teach environmental responsibility in clinical settings.
14	**Life Below Water**	Conserve and sustainably use oceans, seas, and marine resources.	Limit harmful waste disposal from clinics. Educate on the environmental impact of dental products.
15	**Life on Land**	Protect, restore and promote sustainable use of terrestrial ecosystems.	Support sustainable sourcing of dental materials. Reduce environmental degradation from dental waste.
16	**Peace, Justice and Strong Institutions**	Promote peaceful and inclusive societies, access to justice, and accountable institutions.	Promote ethics, patient rights, and professional responsibility. Teach respect, equity, and justice in care delivery.
17	**Partnerships for the Goals**	Strengthen global partnerships to support and achieve the SDGs.	Collaborate with global oral health organizations. Engage students in international outreach and research.

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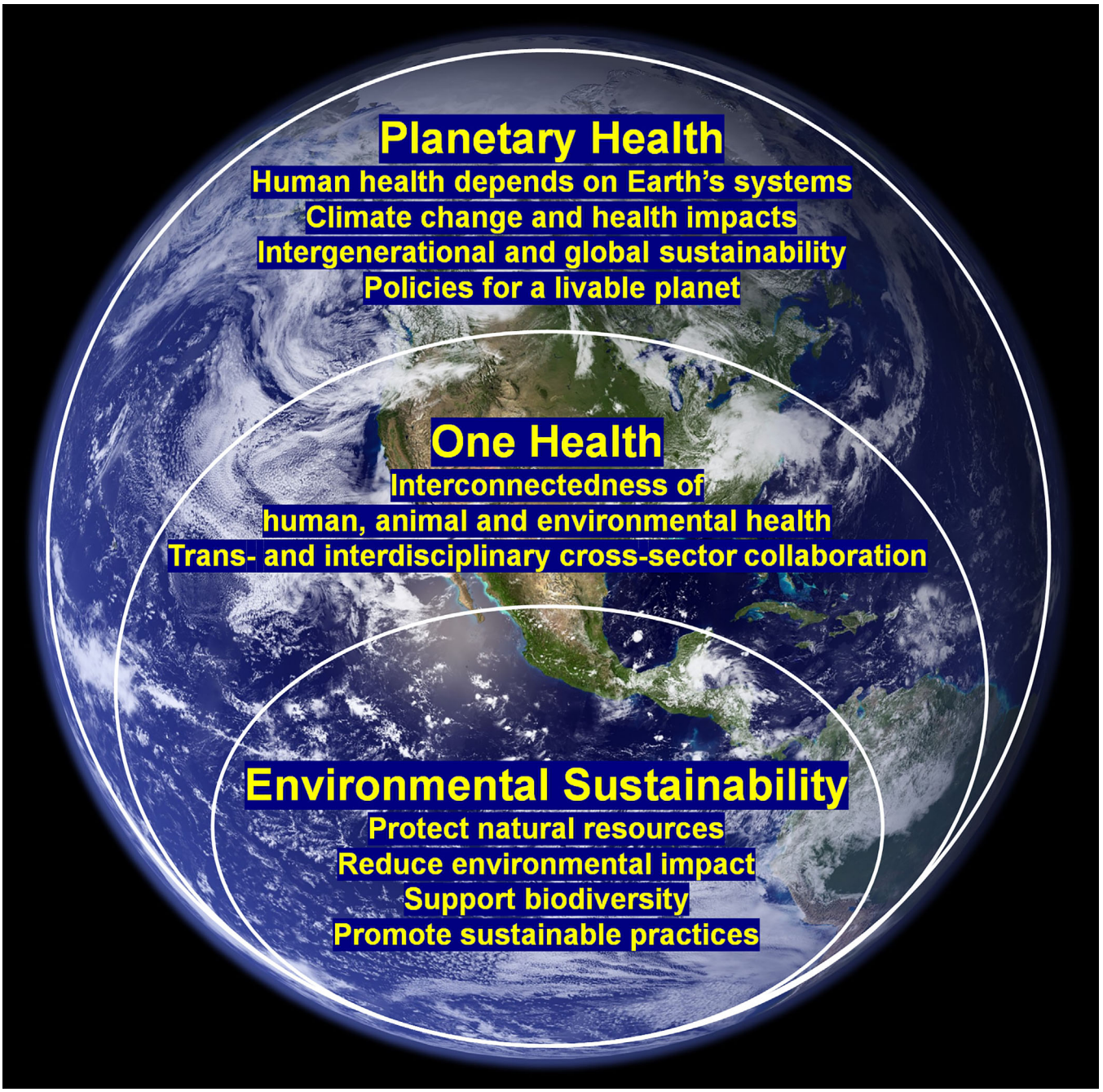


FIGURE 1 | Conceptual relationship between PH, OH, and ES. The nested framework depicts ES as a foundational component of OH, which is situated within the broader domain of PH. PH provides the overarching framework, emphasizing humanity's dependence on Earth's natural systems, the health consequences of climate change, the importance of intergenerational and global sustainability, and policies needed to preserve a habitable planet. Blue Marble. Image and caption adapted from NASA's Visible Earth catalog. *Source*: NASA Goddard Space Flight Center. https://science.nasa.gov/resource/blue-marble, accessed August 10, 2026.

The Planetary Health Report Card (PHRC) is an example of a student-led initiative developed in 2019 by a group of medical students at the University of California, San Francisco [22]. It was created to assess and inspire improvements in how medical schools address climate change, environmental health, and sustainability within their curricula and operations. The project has since grown into an international initiative, with students from numerous medical, dental, and other health professional schools participating across many countries. Dentistry joined in 2022 with a bespoke assessment tool that was developed by academics and students at the University of Sheffield, United Kingdom, and is now used by an increasing number of institutions. The PHRC aims to hold institutions accountable while encouraging education and action on PH.

This student-driven initiative evaluates and compares health professional schools using specific metrics across five categories: PH curriculum; interdisciplinary research in PH; community outreach and advocacy; support for student-led initiatives; and campus sustainability. The PHRC is proving to be a powerful

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advocacy tool that drives change in healthcare higher education institutions by identifying opportunities to mitigate environmental impacts. The report card is published on an open-access platform with an associated grade thus, enabling the participating institution to evaluate and seek to improve its overall environmental performance [23].

2.2 | The Hidden Curriculum

The hidden dental curriculum encompasses the implicit values, norms, expectations, and professional standards conveyed through institutional culture, organizational structures, policies, practices, and patterns of behavior that collectively influence students' professional socialization and identity formation [21]. Integrating PH, OH, and ES into the hidden curriculum therefore requires alignment between the principles articulated in the formal curriculum and the institution's policies, priorities, operational practices, and everyday behaviors. Because the hidden curriculum signals what an institution values in practice, these principles should be consistently and visibly reflected throughout the daily functioning and culture of the dental school. Key approaches may include:

a. Alignment of institutional policies and operations to ensure procurement, waste management, energy use, water conservation, prescribing practices, infection control, and clinical workflows reflect sustainability principles.

b. Socially and environmentally responsible institutional decision-making guiding approaches to resource allocation, health inequities, climate-related risks, and the needs of vulnerable populations.

c. Promoting a clinical culture in which efficient material use, responsible prescribing, waste reduction, prevention, and equitable care are viewed as markers of professional excellence rather than optional activities.

2.3 | The Formal Curriculum

PH, OH, and ES trans- and interdisciplinary education will equip the next generation of learners and practitioners with the knowledge and critical thinking skills necessary to understand the upstream causes of disease, promote health equity, and implement sustainable clinical practices [3, 24]. Such integration will also foster a more resilient, adaptable, and ethically grounded oral health workforce [24].

Dental education associations, including the American Dental Education Association (ADEA) and the Association for Dental Education in Europe (ADEE), have taken the lead to identify and advocate for collaborative mechanisms to address the World Health Organization's (WHO) 'Global Strategy and Action Plan on Oral Health 2023–2030' [25, 26]. Of the six strategic objectives outlined in the Action Plan, the "action area for strategic objective 3: health workforce" focuses on education, with the overarching goal of developing a modern health workforce and advancing and expanding competency-based education [25, 26]. However, the support of these national organizations does not directly drive changes within dental schools to achieve the goals of the Action Plan. In addition, the World Dental Federation (FDI) and ADEE's Sustainability in Dentistry special-interest group have produced numerous educational resources and recommendations for incorporating ES, in particular, into practice [27–30]. Beyond this, at a national level, regulatory bodies including the General Dental Council in the United Kingdom have introduced specific educational learning outcomes for ES within their recent curriculum documentation [31]. Individual higher education institutions are now required to teach and assess these outcomes within their programs, a task that presents a significant number of challenges.

The following case studies demonstrate the mechanisms by which two distinct institutions addressed some of these challenges and successfully translated principles of PH, OH, and ES into integrated, institution-wide approaches to dental education and practice.

2.4 | Case Study One: University of Pennsylvania School of Dental Medicine, USA

In 2024, the University of Pennsylvania School of Dental Medicine (Penn Dental Medicine [PDM]) launched a new predoctoral curriculum that further emphasized integrative learning and included PH, OH, and ES as some of its guiding principles. PDM took the unique approach of incorporating this instruction longitudinally throughout the entire predoctoral curriculum, embedding and integrating related lectures and specific topics within the broader themes of nearly every didactic course. Although this educational initiative will continue to evolve, there are currently 18 lectures or topics (Table 2), including new lectures taught or co-taught by faculty from the University of Pennsylvania School of Veterinary Medicine (PVM), School of Medicine (PSOM), School of Nursing (PN), and the Center for Science, Sustainability and the Media (PCSSM), respectively; this reinforces the interdisciplinary nature of these important principles.

A two-year faculty-wide effort was required to create this comprehensive curriculum, and it further needed the efforts of some faculty champions to identify and seamlessly sequence lectures focused on PH, OH, and ES to fit within the overarching course themes. Highlighted below are selected examples of new educational content added to the curriculum. Except where indicated, all lectures were taught by PDM faculty. At PDM, there are no formal lectures in the fourth-year curriculum.

2.4.1 | First Year Curriculum

Course name: "Building Bridges: Patient Care, Community and Science of Oral Health." This is an interdisciplinary course designed to introduce best practices in patient evaluati and management, concepts of physical and medical evaluation of the dental patient accompanied by an introduction to human form and function, including histology, gross anatomy, physiology, and radiology. The last lecture in this course is an introduction to OH, which requires "building bridges" across disciplines to address the challenges facing

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TABLE 2 | Lectures and topics directly focused on PH, OH, and/or ES within the PDM curriculum and mapped to the SDGs[a].

Academic year	Title	Lecture (L) or topic (T)	Faculty teaching	Sustainable development goals															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	One Health	L	PDM, PVM			X	X							X		X		X		X
1	Sustainable and Equitable Drug Delivery	L	PDM	X		X						X	X		X	X				X
1	Food Systems and One Health for the Whole of Society	L	PVM		X	X								X	X	X		X		X
1	Food Insecurity and Malnutrition	T	PN	X	X								X						X	
1	Emerging Infectious Diseases	T	PDM	X		X			X			X								
1	Opportunistic infections	T	PDM	X		X			X							X				
1	Antimicrobial resistance	L	PDM	X		X			X						X					
1	Environmentally Safe Disposal of Amalgam and Other Dental Materials	T	PDM			X			X			X			X		X			
1	Social Determinants of Health, Trauma Informed Care, and Adverse Childhood Experiences	L	PDM	X	X	X	X			X	X	X	X						X	X
1	Advocacy and Health Policy	L	PDM	X	X	X	X	X				X							X	X
1	Interprofessional Care	L	PDM			X	X	X												X
1	Sustainability, Global Oral Health and Ethics of Mission Trips	L	PDM	X		X	X		X	X	X	X	X	X	X	X			X	X
2	LGBTQ+ Healthcare	L	PSOM			X	X	X			X		X							X
2	Social Determinants of Mental Health	L	PSOM	X	X	X	X	X			X	X	X						X	X
2	Climate Change and Mental Health and Resilience	L	PCSSM			X	X							X	X	X		X	X	X
2	Environmentally Safe Disposal of Pharmaceuticals	T	PDM			X	X		X			X					X			X
3	Environmental Sustainability in Dental Practice: Delivering Oral Health for People, Planet, Peace and Prosperity	L	PDM			X	X		X	X	X	X		X	X	X	X	X	X	X
3	Disaster Preparedness	L (projected)	PDM			X	X					X				X		X		X

Abbreviations: PDM = School of Dental Medicine; PVM = School of Veterinary Medicine; PSOM = School of Medicine; PN = School of Nursing; PCSSM = Center for Science, Sustainability and the Media.

[a]The listed sessions represent the first instance in which they are presented to the students, and in the specific academic year. Some topics, including but not limited to food insecurity, safe waste disposal, sustainability, and gender health and equity, are included in multiple other courses throughout the curriculum in addition to the courses in which they are initially introduced. Except where indicated, all lectures and/or topics are currently incorporated within the predoctoral curriculum. At the time of this writing, the "Disaster Preparedness" lecture is projected to be presented in Spring 2027.

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our planet and strengthen interdisciplinary research [32]. This lecture is co-taught by PDM and PVM faculty, and serves as the foundational lecture in this pan-educational initiative.

Course name: "Cellular and Molecular Basis of Health and Disease." This is an integrated course that includes lectures focused on basic principles of biology and biochemistry, including neoplasia, metabolism, and clinical nutrition. This course includes lectures entitled "Sustainable and Equitable Drug Delivery," "Food Systems and OH for the Whole of Society," and "Food Insecurity and Malnutrition." The drug delivery lecture is focused on novel evidence-based mechanisms aimed to reduce the costs of pharmacotherapeutics and increase access to medications in underprivileged and under-resourced societies. This is taught by a PDM faculty member. The food systems lecture is taught by faculty from PVM. It focuses on how food systems influence social determinants of health, supply chains, and impact the environment. The food insecurity lecture is taught by a PN faculty member. The two latter lectures were new additions to the curriculum.

Course name: "Essentials of Pathology." In addition to a lecture on antibiotic resistance, there is a lecture entitled "Opportunistic Infections" that highlights real-world examples of opportunistic diseases whose incidence increased following natural disasters, including droughts, hurricanes, and wildfires [33, 34]. This topic was a new addition to the lecture. This same lecture also includes a discussion about noma, which is a rapidly progressive and often fatal gangrenous disease of the mouth and face primarily affecting young children living in extreme poverty, especially in regions of malnutrition, poor oral hygiene, and limited access to healthcare [35]. Noma was recently recognized by the WHO as a neglected tropical disease, reflecting the need for integrated public health, oral health, and socio-economic interventions [36].

Course name: "Restorative Sciences I" includes a topic taught by a PDM faculty member focused on the environmentally safe disposal of amalgam and other dental materials.

Course name: "Local and Global Public Health," a pre-existing course in the first-year curriculum that predated the recent curriculum change, was augmented to include a new lecture entitled "Sustainability, Global Oral Health and the Ethics of Mission Trips" taught by PDM faculty.

2.4.2 | Second Year Curriculum

Course name: "Systemic Health and Clinical Medicine." Social environments and structural conditions are integral components of promoting health equity; this is a core principle of OH [1, 2]. To this end, a new lecture focused on "LGBTQ+ Health" was included in this course. This lecture is taught by a faculty member from PSOM. This lecture emphasizes linking biological, environmental, and social factors, promoting collaboration across disciplines to reduce disparities and strengthen resilience. This lecture connects human biology to the social ecosystem (laws, policies, and cultural norms) with consideration of mental health, resilience, and community networks as protective ecological factors. This lecture reinforces the trans- and interdisciplinary approach that OH aims to cultivate [1]. Equipping future professionals to provide culturally competent, inclusive care is essential for population-level health resilience [2].

Course name: "Cognitive Sciences and Pharmacotherapeutics." Lectures entitled "Social Determinants of Mental Health" and "Climate Change and Mental Health and Resilience," taught by faculty from PSOM and PCSSM, respectively, and a topic focused on the environmentally safe disposal of pharmaceuticals taught by a PDM faculty member are included in this course. The resilience lecture and the drug disposal topics were new additions to the curriculum.

2.4.3 | Third Year Curriculum

Course name: "Professional Practitioner Development II" includes a lecture entitled "Environmental Sustainability in Dental Practice: Delivering Oral Health for People, Planet, Peace and Prosperity" taught by a PDM faculty member. This was a new lecture added to the course.

2.4.4 | Other Educational Initiatives

Eliminated amalgam usage within the school.
Increased usage of tele-dentistry.

All students' treatment planning seminar case presentations are now required to include a section that reflects on the environmental impact of the various treatment plans being proposed for the patients. This is an academic exercise to increase students' awareness of the potential environmental costs; it is not being used to guide treatment recommendations to the patients. The students are required to provide information about the biodegradability of the dental materials being proposed, the estimated energy use and carbon footprint associated with fabrication, storage, and delivery of the materials, projected waste generation, and a summary of the net environmental impact with the major contributing factors. Students are asked to rate each of the parameters as "low," "moderate," or "high," with brief explanations. Finally, the students are asked to weigh the environmental impact of each treatment plan against the best care for the patient; this involves balancing the immediate and long-term health benefits of a treatment plan with its sustainability. Students are required to complete this important exercise in years two, three, and four of their dental education.

3 | Mapping Dental Education to the United Nations Sustainable Development Goals

The United Nations SDGs encourage systems thinking and cross-sector collaboration, providing a global framework aimed at eradicating poverty, safeguarding the planet, and promoting peace and prosperity for all by 2030 [19]. Recently, oral health has been linked directly or indirectly to all seventeen SDGs and 37 of 169 SDG targets, with particularly strong relevance to SDGs 3, 4, 6, and 10 [37]. Accordingly, using the SDGs as an educational

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guidepost is another potential strategy for integrating PH, OH, and ES into the classroom. To this end, PDM mapped all didactic lectures and courses to the SDGs (Table 2 and not shown), and will use this mapping to further advance its educational initiative by guiding the identification and development of additional topics and lectures centered on PH, OH, and ES. Table 1 lists general curricular additions that could be considered to address each SDG.

Mapping a dental curriculum to the SDGs is more than just an academic exercise—it situates oral health education within the global agenda for sustainable development and helps future dentists understand their role in advancing health equity, social justice, and planetary well-being. By mapping curricular content to SDGs, it shows students and faculty how their profession contributes to broad global health challenges, and underscores dentistry's integral role in public health, policy, and sustainability [19]. This detailed mapping also shows stakeholders (students, faculty, funders, and regional and global partners) that PDM is committed to sustainable and socially responsible education and clinical practice. To further increase awareness among faculty and students, all PDM didactic course syllabi now include the list of SDGs to which they map.

Many of today's students are motivated by impact and social relevance [38]. Seeing how their coursework addresses the overarching goals of specific SDGs connects personal learning to real-world change; for some students, this may enhance engagement, knowledge retention, and professional identity formation. The exact mechanisms by which the SDGs were mapped to the predoctoral curriculum are beyond the scope of this manuscript.

4 | Next Steps, Including Measuring Impact and Outcomes

This educational initiative is expected to continue expanding through the development and integration of additional meaningful lectures and topics aligned with the framework and overarching themes of the courses. This will require faculty training and capacity building through development of a series of workshops and professional development opportunities to educate faculty about integrating sustainability principles and the SDGs into their teaching. In addition, it will need continued outreach and collaboration, including developing community partnerships, interprofessional initiatives, and educational materials that promote sustainability and climate action beyond the classroom.

Measuring the impact and outcomes of this educational initiative will require a combination of quantitative and qualitative approaches. Since the goal is to change both knowledge and behavior, a series of survey instruments is currently being designed to evaluate at multiple levels: students, faculty, curriculum, institutional practices, and even potential community impact. Examples of some outcomes to be evaluated include:

Students' awareness and understanding of PH, OH, and ES-associated principles before the students begin their dental education and after completion of their dental education. This survey will also measure potential shifts in students' attitudes toward environmental responsibility, including self-reported changes in consumption behavior.

b. Monitoring of student- and/or faculty-led projects to advance climate-conscious practice.

Tracking of faculty engagement in educational workshops and incorporation of related teaching or research.

d. Tracking of institutional policies and actions, including reductions in waste, energy and water savings, adoption of environmentally conscious procurement policies for dental materials, and development of additional PDM-wide sustainability initiatives.

e. Monitoring scholarly and professional outputs arising from this educational initiative, including presentations, publications, and conference talks, as well as the development of collaborations with national and international dental schools and relevant professional and interest-group networks.

4.1 | Case Study Two: School of Clinical Dentistry, University of Sheffield, United Kingdom

Two recent studies have explored the current teaching of ES within European dental curricula and illustrated common opportunities and challenges [30, 39]. Currently, it appears that dental schools agree on the need to embed ES in the curriculum but are unsure how to proceed, especially in clinical areas. Identifying the challenges faced by institutions is a critical step to enable stakeholders to develop tailored guidance to mitigate them. A model to develop/augment existing curricula with supporting examples for ES has been recently published [40]. This model has also been incorporated into ADEE's Graduating European Dentist online webpages [41].

Using this model, the two undergraduate clinical programs (Dentistry and Dental Hygiene and Dental Therapy) at University of Sheffield have been augmented to incorporate ES across all years of study. This has been achieved through a systematic, educational research-centered approach to develop tailored educational content and strategies and to test the effectiveness of the selected approaches. The approaches adopted by University of Sheffield are detailed below, following each step of the curriculum development model [40].

4.1.1 | Situational Analysis and Needs Assessment

The core situational analyses and needs assessments were described earlier when considering existing practice to teach ES in dental education and understanding the challenges and drivers for change [5, 16, 17, 30]. Additional context for the proposed changes was achieved from the outputs of the "O-Health-Edu" project, which detailed key educational practices across the European continent [42–46]. Student support for the inclusion of the topic in the curriculum was widely reported across numerous countries, and these data were supplemented locally through a national survey [47]. The existing curriculum map was reviewed to establish key institutional thresholds for change.

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4.1.2 | Definition of Learning Outcomes

The learning outcomes for the ES-focused teaching interventions were drawn from a pan-European consensus document created by the "Sustainability in Dentistry" special-interest group within ADEE [18]. This article outlined consensus-agreed learning outcomes, along with recommended teaching and assessment methods for ES in oral health professional education [18]. These outcomes were aligned with the existing Graduating European Dentist curriculum framework and have been incorporated into most recent versions [48]. This work presented one of the first attempts to define the desired knowledge, skills, and behaviors of graduating dentists in relation to ES [49]. Utilizing consensus-based methodology to explore the views of a diverse group of educators representing multiple countries, three learning outcomes were selected from this documentation for implementation at University of Sheffield:

- Describe the key principles of sustainable oral healthcare, including environmental considerations and patient adherence, and identify factors influencing the implementation of sustainable practices.
- Assess and apply the evidence regarding the environmental impacts of common treatment methods and approaches to oral healthcare delivery.
- Create patient-specific preventive oral health strategies that minimize the need for recalls, operative interventions, and material use.

4.1.3 | Selection of Methods of Teaching and Assessment

In addition to the teaching and assessment methods outlined in the ADEE position paper published in 2023 [18], focus groups with faculty/staff and students were conducted to explore opportunities to embed ES into the existing curriculum at University of Sheffield [48, 49]. Thematic analysis of the focus group transcripts generated five themes that informed the planned teaching and assessment methods:

- *Normalizing the topic of ES to support attitude and behavior change*—the topic must be embedded into the ethos of the institution and longitudinally embedded in the curriculum.
- *Providing foundational knowledge along with relevant practical applications*—there is a need to develop core knowledge of ES, PH, and climate change early in programs. ES must not be an isolated topic; it must be reinforced in practice given the nature of the profession.
- *Reframe and adapt existing teaching and assessment activities*—due to challenges with curriculum overload, higher education institutions can augment existing activities to include ES rather than adding new curricular items.
- *ES spans across all disciplines within dentistry and oral healthcare*—ES must be taught across all curriculum subjects, from non-clinical basic sciences to all clinical specialties.
- *Safeguarding against misinformation and disinformation*—evidence-based educational content must be developed and delivered to students. Information literacy and governance must also be taught to students to develop critical thinking and appraisal skills.

This exploratory work informed a strategy to embed ES across all years of study at University of Sheffield (Table 3).

4.1.4 | Content Development and Organization

The reported challenges in low staff confidence and awareness to teach ES established a clear need to develop evidence-based content across all curriculum subjects. Key messages were developed from the evidence base for ES in dentistry and formulated into "content statements" that could be incorporated into existing teaching events [49]. This work was validated through an extensive consultation process to ensure understandability (students), relevance (discipline experts), and applicability (educational experts). Forty-four content statements were finalized and mapped to all curriculum subjects in dentistry, including non-clinical and clinical disciplines. The mapped content statements were subsequently incorporated into discipline-based slide decks and staff/faculty were supported to incorporate a small number of slides into their current teaching where applicable. This work was adopted by the FDI and the slide decks are available as open-access resources [50].

4.1.5 | Implementation and Evaluation

The previous steps informed a strategic plan to embed ES into the formal curriculum from September 2024. To evaluate the effectiveness of the interventions from a learner perspective, the attitudes, awareness, and knowledge of oral health professional students in relation to ES in dentistry was measured pre- and post-teaching interventions through a survey [5]. This work revealed statistically significant positive changes in these outcome measures from baseline to post-intervention, demonstrating that these approaches are effective at increasing awareness and knowledge of ES, but also, importantly, can begin the process of attitudinal change, which may inform future behavior. In addition, ES has been incorporated into existing student evaluations, including single-best-answer and short-structured-answer examinations, as well as OSCEs and clinical case presentations.

Open-access resources to support education in ES and the incorporation of ES in the oral health curriculum are presented in Table 4.

5 | Discussion

Sustainable healthcare benefits both the environment and society by supporting disease prevention and improved health outcomes, encouraging patients to take a more active role in their health, and improving economic efficiency [51]. Accordingly, dentistry has an ethical responsibility to advance practices that reduce environmental harm while strengthening the health and sustainability of the healthcare system.

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TABLE 3 | Teaching interventions for ES delivered as part of the core curriculum at University of Sheffield.

Educational aim	Proposed teaching methods	Year of study
Learn core environmental sustainability, Planetary Health and climate change content	FDI World Dental Federation "Sustainability in Dentistry MOOC"	Year 1 Dentistry Year 2 Dental Hygiene and Dental Therapy
	Environmental sustainability in oral healthcare lecture	Year 1 Dental Hygiene and Dental Therapy Year 2 Dentistry
Learn about the subject of dentistry and its relationship to environmental sustainability	Incorporate environmental sustainability content into existing teaching events (FDI slide decks)	Twenty-one events across Years 1–4 Dentistry Twelve events across Years 1 and 2 Dental Hygiene and Dental Therapy
Learn about strategies to mitigate environmental impacts in patient care settings	Case-based discussion centered around patient care and environmental sustainability	Years 4 and 5 Dentistry

TABLE 4 | Open-access resources to support education in ES in dentistry and the incorporation of ES in the oral health curriculum.

Environmental sustainability in dentistry educational resources	Link
FDI Sustainability in Dentistry MOOC (Part 1)	bit.ly/FDI-ES-MOOC
FDI Sustainability in Dentistry MOOC (Part 2)	bit.ly/FDI-ES-MOOC2
ADEE Learning Outcomes for ES	bit.ly/ADEE-ES-LO
Evidence-based Content for ES	bit.ly/ES-CONTENT
FDI Slide Decks for ES	bit.ly/FDI-ES-SLIDES
Implementation and Evaluation of ES in the Curriculum	bit.ly/ES-CURRICULUM-EVALUATION
Curriculum Development Process with Practical Examples for ES	https://onlinelibrary.wiley.com/doi/10.1111/eje.13145?af=R

Education at every level of the profession has been identified as a key strategy for reducing environmental impacts [16, 51]. However, the foundational values of the profession are established early in dental education, where they shape attitudes and foster the behaviors expected of future dental professionals. Preparing dental students to understand and act upon the interconnectedness of human, animal, and environmental health is therefore essential for building a more sustainable and equitable future.

Integrating PH, OH, and ES into predoctoral dental education can broaden the traditional emphasis on procedures and disease treatment by promoting a more holistic, patient- and environment-centered model of care informed by local and global ecological, social, and clinical perspectives. The goal is not to displace the core dental sciences, but to evolve the professional identity of future practitioners and equip them with the competencies needed to address emerging clinical, environmental, and societal challenges.

6 | Conclusion

The future relevance of dentistry may depend, in part, on its ability to look beyond the operatory and engage with the broader systems that shape health. Dental education will be central to developing practitioners who recognize these relationships and make decisions informed by consequences that extend beyond the individual patient. Rather than simply adding content to an already crowded curriculum, integrating PH, OH, and ES into dental education represents an investment in a profession better prepared to respond thoughtfully, collaboratively, and effectively to the challenges that will influence oral health in the decades ahead. Realizing this vision will require sustained institutional commitment, faculty development, interdisciplinary collaboration, and purposeful integration across existing clinical and educational frameworks. The time to begin this transformation is now.

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Conflicts of Interest

The authors declare no conflicts of interest.

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