Curriculum development in dental education through the lens of environmental sustainability

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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School of Clinical Dentistry

December 2024

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Abstract

Dental education must evolve to remain fit for purpose in a changing society. A curriculum development cycle must be in place to enable dental schools to respond to key drivers of change. The dental curriculum must fit the vision of multiple stakeholders, including educators, students, universities, regulators and the local population. Previous models of curriculum development principally refer to extensive changes and fundamental shifts in curriculum philosophy. A model to demonstrate how the *existing* curriculum can be refined and updated is necessary. This study sought to systematically develop a new model of curriculum development through an educational research approach by using environmental sustainability (ES) as an example of an emerging topic that must be included in dental education. Multiple methodological approaches, including scoping reviews and surveys, were utilised to establish a comprehensive situational analysis of dental education across Europe and the current teaching practice of ES. Specific learning outcomes of ES and aligned teaching and assessment methods were developed through a consensus-based approach with stakeholders from across Europe. In a local context, focus groups with educators and students identified key opportunities to embed ES in the local curriculum and established the need to teach ES across all disciplines with practical reinforcement. Evidence-based subject-specific content was developed to facilitate the delivery of scientifically grounded ES teaching by educators of all disciplines. This research informed a plan to embed ES within the local dental curriculum and a survey was developed to assess the impact of ES teaching interventions. This demonstrated significant positive changes in students' awareness, attitudes and knowledge of ES in dentistry. Conclusions derived from this research demonstrate that it is feasible to incorporate new topics into the dental curriculum with minimal disruption. A new model of curriculum development has been validated through a research approach grounded in stakeholder collaboration.

Acknowledgements

I would like to express my sincerest gratitude to my supervisors Professor Nicolas Martin, Professor James Field and Dr Harriet Baird. This thesis was only possible with their support, expertise, guidance and mentorship. Specifically, I would like to thank my primary supervisor, Professor Nicolas Martin, for his unwavering support and his leadership in the research field of Environmental Sustainability in Dentistry, which provided me with immense motivation. I would also like to thank Professor James Field for his continuous support and expertise in dental education; the leadership he has demonstrated in his career has pushed me to develop as a researcher and educator. My thanks also go to Dr Harriet Baird for her guidance and support in developing attitudinal and awareness scales; your expertise and approach to research have been inspiring.

I would also like to thank all my colleagues at the School of Clinical Dentistry, University of Sheffield, for their support. Our outstanding students were very willing to participate in numerous research projects and directly contributed to this important curriculum development project. My staff colleagues were also very supportive and participated in multiple events that were fundamental to the success of my research project.

Finally, I would like to express my sincerest gratitude to my family. Thank you to my wife, Mago, and daughter Emi for their love, understanding, and encouragement. Thank you to my parents, brothers, and extended family for their support.

PhD by Publication – Candidate Statement

This thesis is submitted in the format 'by publication' as per the regulations set out by The University of Sheffield Guide to the thesis examination process for candidates of research degree programmes, October 2024.

Accordingly, the thesis is organized into chapters, each providing commentary linking the work to peer-reviewed manuscripts published within the last five years.

The candidate, Jonathan Dixon, confirms that the PhD thesis and the included manuscripts are the candidate's own work as principal investigator and first author. The candidate, Jonathan Dixon, also confirms that he has made a significant contribution in collaboration with others for the co-authored publications.

Principal Investigator and first author

- **Dixon J**, Manzanares-Cespedes C, Davies J, Vital S, Gerber G, Paganelli C, et al. O-HEALTH-EDU: A scoping review on the reporting of oral health professional education in Europe. European Journal of Dental Education. 2021;25(1):56–77.
- **Dixon J**, Field J, Vital S, van Harten M, Roger-Leroi V, Davies J, et al. O-HEALTH-EDU: A viewpoint into the current state of Oral Health Professional education in Europe: Part 1: Programme-level data. European Journal of Dental Education. 2024 May 1;28(2):591–606.
- **Dixon J**, Tubert-Jeannin S, Davies J, van Harten M, Roger-Leroi V, Vital S, et al. O-Health-Edu: A viewpoint into the current state of oral health professional education in Europe: Part 2: Curriculum structure, facilities, staffing and quality assurance. European Journal of Dental Education. 2024 May 1;28(2):607–20.
- **Dixon J**, Field J, van Harten M, Duane B, Martin N. Environmental Sustainability in Oral Health Professional Education: Approaches, Challenges, and Drivers—ADEE Special-Interest Group Report. European Journal of Dental Education [Internet].

2024 Aug 13 [cited 2024 Sep 10];n/a(n/a). Available from: https://doi.org/10.1111/eje.13033

- **Dixon J**, Martin N, Field J. Current practice, barriers and drivers to embedding environmental sustainability in undergraduate dental schools in the UK and Ireland. British Dental Journal. 2024 Nov 1;237(9):723–8.
- **Dixon J**, Field J, Gibson E, Martin N. Curriculum Content for Environmental Sustainability in Dentistry. Journal of Dentistry. 2024 Apr 26;105021.

Co-authored collaborative publications

Co-authored manuscripts are included to provide important contextual background to the thesis. The candidate has made a significant individual contribution to the conceptualisation, research implementation, data analysis and write-up of these collaborative projects that have been published in peer-review journals.

- Davies JR, Field J, **Dixon J**, Manzanares-Cespedes MC, Vital S, Paganelli C, et al. ARTICULATE: A European glossary of terms used in oral health professional education. European Journal of Dental Education. 2023;27(2):209–22.
- Field J, **Dixon J**, Davies J, Quinn B, Murphy D, Vital S, et al. O-Health-Edu: A vision for oral health professional education in Europe. European Journal of Dental Education. 2023 May;27(2):382–7.
- Field J, Martin N, Duane B, Vital S, Mulligan S, Livny A, Lindberg P, Lundegren C, Long R, Lundbeck H, Ramasubbu D, **Dixon J**. Embedding environmental sustainability within oral health professional curricula—Recommendations for teaching and assessment of learning outcomes. European Journal of Dental Education. 2023;27(3):650–61.
- Durnall O, Martin N, Mulligan S, **Dixon J**. Environmental sustainability: the attitudes and experiences of UK students in the oral health care profession. British Dental Journal. 2024

Signed by the Candidate, Jonathan Dixon

13th December 2024

Glossary of Terminology and Abbreviations

ADEE – Association for Dental Education in Europe

BDS – Bachelor of Dental Surgery

CED – Council of European Dentists

CO_2-eq – Carbon Dioxide equivalent

CPD – Continuing Professional Development

DH&DT – Dental Hygiene and Dental Therapy

ECTS – European Credit Transfer System

ENQA – European Association for Quality Assurance in Higher Education

ES – Environmental Sustainability

ESD – Environmental Sustainability in Dentistry

FDI – Fédération Dental Internationale – FDI World Dental Federation

GDC – General Dental Council

GED – Graduating European Dentist

HEI – Higher Education Institution

IPCC - Intergovernmental Panel on Climate Change

ISO – International Organization for Standardisation

LCA – Life Cycle Assessment

MOOC - Massive Open Online Course

NHS – National Health Service

OHP – Oral Health Professional

OSCE – Objective Structured Clinical Examination

PBL – Problem-based Learning

SDG – Sustainable Development Goals

SUP – Single-use Plastic

UK – United Kingdom

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Chapter I – Introduction

This research project investigates how the undergraduate dental curriculum develops in response to an external disruptor, such as environmental sustainability (ES).

Medical and dental curricula have changed significantly over the years, moving from a traditional, teacher-centred Flexnerian approach to more contemporary student-centred and learning outcomes-based approaches [1–4]. In addition to these fundamental changes in the overarching philosophy of curricula, they have also had to develop and adapt to changes on a 'smaller' scale. New developments in dentistry, educational innovation and changes in society and stakeholder priorities all drive curriculum development [5–9]. Examples of changes to the dental curriculum over the past 20 years include the increasing popularity of adhesive materials and minimal intervention dentistry, the recognition of the importance of psychology in dentistry and the necessary inclusion of topics such as ethics and professionalism. A curriculum development process with regular internal and external quality assurance is necessary to ensure emerging issues are embedded effectively with minimal disruption.

ES presents a current and challenging subject for inclusion in the undergraduate dental curriculum. Increasingly, there is a realisation that all sectors must make fundamental changes to their practices to mitigate environmental impacts. Dentistry and oral healthcare provision have a significant environmental 'footprint' with respect to carbon dioxide equivalent (CO_2-eq) emissions, pollution and a loss of biodiversity [10,11]. Travel associated with dentistry, principally patient travel to the dental practice and staff commute to their place of work, contributes to approximately 60% of carbon emissions [10]. Other substantial contributors include procurement of materials, equipment and clinical items, energy, gas and water consumption, dental material use, and waste management. Healthcare services, national regulators and other professional bodies are now prioritising and promoting more environmentally sustainable practices [12–15]. A critical approach to achieving these aims is raising awareness through education at all levels [16].

The need to embed ES in the undergraduate dental curriculum has been established and is driven by a need to promote behaviour change in the emerging profession and to comply with educational and professional conduct legislation. Sustainability has been defined as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* [17]. The core concept behind this definition applies to environmental sustainability in dentistry (ESD), where it is proposed that immediate and long-term strategies should be employed to mitigate environmental impacts associated with oral healthcare.

Multiple curriculum development models have been published, although most primarily focus on fundamental changes in educational philosophy that require a comprehensive curriculum review [8,18,19]. The reality is that most schools cannot complete a full-scale curriculum review frequently; it is unnecessary in most contexts and is not sustainable from a workload perspective. Therefore, a model that describes a process of pragmatic development of the existing curriculum is necessary. Kern's model of curriculum development is a commonly cited tool; however, the terminology might now be considered outdated [5]. A contemporary model of curriculum development that supports dental schools in augmenting and refining their programmes is necessary. The new model should consider the unique nature of dental education and be grounded in contemporary educational practices such as a learning outcomes-based approach, stakeholder inclusivity and regular quality assurance.

There is a need to better understand how undergraduate dental education is delivered, how curriculum development occurs in response to emerging curriculum disruptors and how ES relates to dental education. This will be explored through a comprehensive literature review that aims to answer the following primary and secondary research questions.

Primary Research Question

How does the undergraduate dental curriculum evolve to incorporate new concepts, such as environmental sustainability?

Secondary Research Questions

- How are dental curricula currently structured and delivered?
- How does dental education vary across Europe?
- How do dental curricula develop in response to emerging challenges?
- What is the environmental impact of dentistry and how can this be mitigated?
- Is environmental sustainability currently taught in dental programmes?
- What strategies should be employed when teaching environmental sustainability in dental programmes?

Chapter II – Literature Review

Introduction

This literature review will address the research question *'how does the undergraduate dental curriculum evolve to incorporate new concepts, such as environmental sustainability?'* by thoroughly and systematically searching, selecting, and critically appraising the relevant literature. The outcome of the literature review will be the development of appropriate research hypotheses, aims and objectives as a foundation for future investigations. Therefore, this literature review will describe a current understanding of dental education and the definition and components of the curriculum. A European directive currently dictates dental education across the continent, so an overview of dental education and curriculum practices across Europe will be considered. Pressures and challenges to the dental curriculum and how the curriculum develops in response to these will be examined. Environmental sustainability in dentistry (ESD) will subsequently be investigated, and finally, a review of this topic in dental education will be conducted. Currently, different terms are used in the literature to describe the wider dental team, with oral health professional (OHP) being favoured. The terms 'OHP' and 'dental' will be used interchangeably throughout this thesis, depending on the context discussed. 'Dental' education will refer to dentistry programmes exclusively, whilst 'OHP' education will refer to the training of dentists and other OHPs, including hygienists, therapists, assistants and clinical dental technicians.

Methodology

A comprehensive search strategy was developed to ensure relevant, high-quality literature was identified. The strategy included the use of medical (PubMed, MEDLINE, Web of Science) and educational databases (ERIC) and hand-searching the reference lists of retrieved sources. No limitations were placed on the search period and only sources in the English language were included. A primary list of search terms was developed from the

research question, although additional searches were performed as the review progressed to ensure that all relevant literature was identified. The primary search terms were:

1. Dent* [title] AND education [title]
2. Oral [title] AND education
3. Dent* [title] AND curricul* [title]
4. Oral [title] AND curricul* [title]
5. Curricul* [title] AND change [title]
6. Curricul* [title] and development [title]
7. Dent* [title] AND sustainab* [title]
8. Oral [title] AND sustainab* [title]
9. Dent* [title] AND environ* [title]
10. Oral [title] AND environ* [title]
11. Dent* [title] AND eco* [title]
12. Oral [title] AND eco* [title]
13. Education [title] AND sustainab* [title]
14. Education [title] AND environ* [title]
15. Education [title] AND eco* [title]
16. Curricul* [title] AND sustainab* [title]
17. Curricul* [title] AND environ* [title]
18. Curricul* [title] AND eco* [title]

The literature search aimed to be systematic and flexible, considering all literature regardless of the research methodologies employed. It ran from October 2019 to July 2024, with regular reviews to ensure all up-to-date sources were included. Sources were screened after reading the abstract and included if they were relevant to the research question. There were no date limitations, although only publications in English were accepted.

Outline of the Literature Review

- Dental Education
    - The Origins of Dentistry and Dental Education
    - Defining Dental Education
    - Defining the Curriculum
    - How is Dental Curriculum Delivered?
    - The Nature of Learning, Teaching and Assessment in Clinical Dentistry
    - The Capabilities of the Graduating Dentist
    - Stakeholders of Dental Education
    - Attempts to Promote Convergence of Dental Education in Europe
- Curriculum Development in Response to Emerging Pressures and Challenges
    - The Evolving Dental Curriculum
    - Drivers for Curriculum Change
    - The Challenges Facing Higher Education Institutions
    - Curriculum Development Models
- Environmental Sustainability in Dentistry: An Emerging Challenge
    - What is Environmental Sustainability?
    - Is Dentistry Currently Sustainable?
    - Strategic Environmental Concepts to Achieve Change in the Profession
    - Areas of Focus to Deliver Strategic Environmental Concepts
    - Cross-cutting Strategies for Environmentally Sustainable Dentistry
    - Focused Strategies for Environmentally Sustainable Dentistry
    - Drivers and Barriers to Environmentally Sustainable Change in Dentistry
- Environmental Sustainability in Undergraduate Dental Education
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- Key Principles to Embed Environmental Sustainability in Undergraduate Dental Education
- Examples of Environmental Sustainability Educational Interventions

1. Dental Education

1.1. The Origins of Dentistry and Dental Education

In the simplest terms, dentists are healthcare workers who diagnose, prevent and manage oral diseases and conditions. The term dentist is synonymous with dental practitioner and dental surgeon. A glossary for oral health professional education provides a more comprehensive definition of a dentist: *"a dental professional who has successfully completed basic dental training and is licensed to perform all activities involving the prevention, diagnosis and treatment of anomalies and diseases of the teeth, mouth, jaws and associated tissues"* [20]. This begins to reflect the complex definition of a dentist and considers "*basic dental training*" or undergraduate dental education, as well as licensing and registration within individual countries or geographic regions.

A dentist forms a part of the OHP workforce, which can include dental hygienists, therapists, nurses or assistants and clinical dental technicians [21] . The range of activities a dentist can perform, termed the "Scope of Practice", is often outlined by dental regulators within each country. In the United Kingdom, the General Dental Council (GDC) is the regulator and has outlined the scope of practice for all OHPs in the Scope of Practice document [22]. The GDC places heavy emphasis on continuing professional development (CPD) so that OHPs can acquire additional skills which may add to their scope of practice, but they also ask professionals to *"maintain, develop and work within your professional knowledge and skills"* [23]. It is anticipated that the scope of practice of dentists across Europe is similar, although there is limited evidence to support this notion. Although the presence of published European-wide curriculum documents, including the profile and competencies of the Graduating European Dentist (GED), suggests this is the case [4,24,25].

The earliest reports of dental treatment date back to around 13,000 years ago [26]. At this time, dental interventions were carried out to manage pain, and knowledge of these procedures was passed on through word of mouth. Dental education progressed to an apprenticeship model in the 18th century when Pierre Fauchard published '*Le Chirurgien Dentiste*' [27]. Fauchard is recognised as the father of modern dentistry, and several dental procedures are described in this book. At this point, dentistry was first recognised as a profession [28]. While the profession of dentistry was first developing, there was little global alignment or consensus on its definition and education. From this, two principal theories of dental education were born: the Odontology and Stomatology models [29].

In the Stomatology model, dentistry is effectively seen as a speciality within General Medicine [30,31]. Countries administering this model require students to obtain a primary medical degree and subsequently undertake further dental training [32]. This model was mostly employed in Eastern Europe, although Stomatology was a recognised discipline in Italy and Spain in the 1980s and Austria in the 1990s [30,32]. Nowadays, the discipline of Stomatology is largely redundant worldwide.

The Odontology model is the principal model of dental education today. This model views dentistry as an independent discipline, and programmes are delivered in dedicated schools or departments within a higher education institution (HEI)[29,31,32]. This began in the United States in 1840, when Horace Hayden and Chapin Harris opened the Baltimore College of Dental Surgery, the first dental school in the world. This model of dental education was quickly adopted by countries in Northern and Western Europe (United Kingdom, France, Germany), with the first dental school in Europe opening in 1859 in London [31,32]. These were the first steps towards a contemporary dental education in Europe. However, these were still very early days, and the dental profession and education were largely unregulated [26,29].

1.2 Defining Dental Education

Throughout the years, there have been many definitions of education, including those provided by Aristotle, Socrates, and John Dewey. Dewey viewed education as *"a process of living"* and attributed education to the growth of a person [33]. Malcolm Knowles also stated that the *"heart of education is learning"* [34]. Whilst by no means comprehensive definitions of education, the core tenet of education is student learning. If we consider learning to be the heartbeat of education, all the activities that facilitate, support, and measure this learning form a part of education. These processes include teaching and learning content, resources and methods, assessment, administrative and organisational matters, evaluation and quality assurance, student admission and student support services.

Dental education employs all the previously described processes with a focus on dentistry. However, the definition, scope and content of undergraduate dental education have not been fully explored [35]. Today, dental education in the European Union (EU) must follow the legislature set out in the EU directive 2005/36/EC on the recognition of professional qualifications, which was most recently updated in 2013 [36,37]. According to this legislature, dental education in Europe *"shall comprise a total of at least five years of study, which may in addition be expressed with the equivalent ECTS credits, and shall consist of at least 5000 hours of full-time theoretical and practical training"* and the programme must be *"provided in a university, in a higher institute providing training as being of an equivalent level or under the supervision of a university"* [37].

The output of undergraduate dental education is a graduating dentist who can, in most cases, register and practice dentistry within the country of graduation. The definition of graduating dentist capabilities is complex and will be discussed in more detail later in this literature review.

Numerous authors have described the overarching aim of dental education; the simplest of these was by Banoczy, who stated, "The goal of dental education may be defined as the formation of dentists, who are able to provide the possible best oral health care under

given circumstances" [30]. According to Scott, dental education aims "to produce a dental practitioner who is ethical, competent to practice general dentistry at a level commensurate with the reasonable expectations of the society he or she is destined to serve and committed to career-long educational and professional improvement" [32]. This more detailed aim begins to describe some of the capabilities that future dentists must acquire during their undergraduate dental education programme, including the concept of lifelong learning.

Chuenjitwongsa *et al.* [35] categorised the components of undergraduate dental education into: input, process, institutional issues, external factors and output. These groups have been further explored in Table 1. Organising the components of dental education in this manner allows for a global view of all individual components that contribute to reaching the output of a qualified dentist.

Table 1 - The input, process, institutional issues, external factors and output components of undergraduate dental education, a modified version of the work described by Chuenjitwongsa et al.[35].

<table>
<tr><th>Input</th><th>Process</th><th>Institutional Issues</th><th>External Factors</th><th>Output</th></tr>
<tr><td rowspan="2">Student Admission and Selection</td><td>Teaching and Learning</td><td>Organisational Structure</td><td>Local Healthcare Needs and Healthcare System</td><td rowspan="2">Safe Beginner/ Safe Practitioner/</td></tr>
<tr><td>Assessment</td><td>Administration</td><td>Relationships with Stakeholders (Healthcare Provider, Regulator, Professional Bodies, Educational Bodies)</td></tr>
</table>

<table>
<tr><td rowspan="2">Widening Participation Activities</td><td>Student Support and Progress Committees</td><td>Finances</td><td>Changing Profession/Workforce</td><td rowspan="4">Prepared for Lifelong Learning

Achieved Defined Learning Outcomes</td></tr>
<tr><td>Quality Assurance</td><td>Faculty/Staff Recruitment, Retention and Development</td><td>Changes in the Discipline</td></tr>
<tr><td rowspan="2">Other Higher Education Promotional Activities</td><td>Resources</td><td rowspan="2">Relationship and Collaboration with Wider University</td><td rowspan="2">Research</td></tr>
<tr><td>Environment</td></tr>
</table>

1.3 Defining the Curriculum

The dental education literature frequently refers to '*the curriculum*', often without a clear definition. The etymology of the term dates back to the Latin word "*currere*", meaning 'to run the course', and thereby relates to progressing through a course of study [38]. The definition of curriculum is contentious, with disagreement amongst educators [39–43]. Burton & McDonald [40] even stated that the term does not *"readily lend itself to a dictionary-style definition"*. There is an assumption in the literature that educators have an implicit understanding of the curriculum, as the term is rarely defined in these manuscripts. To further complicate the issue, the term "curriculum" is homonymous; it can mean different meanings in varying contexts.

The simplest definition of 'curriculum' is a syllabus or a course of study [38,43–45]. The idea that a curriculum is simply a list of the subjects or content to be covered in a programme is quite limited -however, this is a common interpretation of the term amongst educators

[40,42]. Other definitions include the syllabus alongside learning, teaching, and assessment methods as a collective for the curriculum [42,46–49]. With these definitions, there is a clear theme of a formal and explicit plan for a course of study that educators deliver and assess. Arguably, this is quite a teacher-centred approach to the curriculum with a focus on the actions, knowledge, and responsibilities of the educator.

In line with more contemporary educational thinking, many authors and educators perceive the curriculum as planned learning within a programme of study [5,38,40,42,50]. In this sense, the curriculum may be a framework to facilitate learning [50]. The focus on learning is preferable, as that is the output of any educational programme, moving from a traditional teacher-centred approach to a student-centred approach [18]. Nevertheless, purely focusing on what is learnt limits the remit of the term to planned and formal events.

Hafferty [51] states that the curriculum is comprised of three parts: the formal curriculum, the informal curriculum, and the hidden curriculum. This highlights the fact that, aside from the formally delivered curriculum, informal but deliberate interventions by educators form part of the curriculum, as well as the unintended messages transmitted to students from educators and the surrounding environment and ethos of an institution. Harden [52] distinguishes the taught curriculum (the teaching that is delivered) from the declared curriculum (assumed learning) and the learned curriculum (the actual learning). Similarly, Prideaux [38] states that the curriculum occurs at three levels: what is planned, what is delivered, and what is experienced by the students. These models highlight the challenges of defining the curriculum and the complex and unpredictable relationship between teaching and learning. It is clear from these definitions and constructs that the curriculum is centred around student learning and is composed of formally planned pedagogic interventions but also includes informal and sometimes unintended learning.

A curriculum may also be described from a product or “end-goal” point of view by focusing on the goals or objectives that should be achieved at the end of a programme [40,42,46,48,52,53]. These goals are termed “learning outcomes” and outline the knowledge and/or skills a learner should acquire upon completion of a learning event. Learning outcomes form the

foundation of the now commonly accepted outcome-based education, as described by Harden [2].

Many of the components of the curriculum have been described above when considering the various definitions of the term. The literature in this area of research is not well-aligned, with different authors providing different interpretations. The following list is an amalgamation of the various components of the curriculum stated by different educationalists and presents a comprehensive view of all identified curricular components:

- Aims of the programme of study [40,42,46,48,50]
- Learning outcomes [50,52]
- The content to be learnt [38,40,46,50,52,54]
- Teaching and learning methods [38,40,42,46,48,50,52,54]
- Assessment methods [38,40,46,48,50,52,54]
- Monitoring and evaluation processes [38,50]
- Student recruitment and selection processes [40,50]
- Learning resources [50,52]
- Learning environments and experiences [50,52]
- Student support and guidance processes [50]
- Staffing matters, including recruitment, selection, timetabling and responsibilities [40,52]
- Programme organisation, communication, and timetabling [46,52]
- Hidden meanings and values derived from the learning experience, the hidden curriculum [40,52]

The lack of concordance between educators makes creating a comprehensive definition of curriculum challenging. The curriculum includes all contact, experiences and exchanges within an institution that promote learning on a student's journey through an institution [42,55]. Burton and McDonald [40], after observing a wide range of views from educators in medical education, understand the curriculum to include: *"what is taught (syllabus) and*

why; where; when and in what form teaching and learning take place; how learning is assessed; who is teaching; the preconceptions of those being taught; the selection of teachers and learners; and, in addition, all the hidden meanings and values derived from the learning experience". This serves to reinforce the broad remit of a comprehensive definition of the curriculum where the "*whole is greater than a sum of the parts"* [47].

In summary, the term curriculum is complex to define, and educators perceive the term differently, which may vary depending on the situation. Annala [43] found that in curriculum theory research, "*syllabus, product, process and praxis"* are frequent themes and these align with the various definitions described previously in this section. For the remainder of this document, the term 'curriculum' describes the cumulation of learning that students experience and acquire by the end of a programme of study. This learning may be planned, unplanned, formal, informal, or hidden from educators. It relates to an educational institution's structure, attitude, ethos, and environment and contains all of the planned content, learning outcomes, pedagogic techniques and assessment methods.

1.4 How is the Dental Curriculum Delivered?

According to the EU directive for professional qualifications (2013/55/EU), undergraduate dental programmes must comprise at least 5 years of study and consist of at least 5000 hours of theoretical and practical training [37]. Annex V3/5.3.1 of Directive 2005/36/EC describes the *"study programme for dental practitioners"* and separates dental programmes according to basic, medico-biological and dentistry-specific subjects [36]. However, the Council of European Dentists (CED) has proposed changes by updating the terminology across all subjects and adding new subjects to better mirror contemporary dental practice [56]. The CED also recommended changing the three principal groups to: (i) basic sciences (ii) medico-biological sciences and preclinical dentistry and (iii) comprehensive clinical experience with patients. The changes to Annex V.3/5.3.1 were also supported by the Association for Dental Education in Europe (ADEE).

Dental schools across Europe use these core requirements to establish their curricula at an individual school level [25]. Numerous sources help dental schools build their own curricula, some mandatory and others serving as guidance [1,4,15,57–62]. These will be discussed later in this literature review.

Historically, the structure of undergraduate dental programmes has been rigid and hierarchical. Dental students typically first studied the basic sciences; this early theoretical teaching provided students with the opportunity to learn the fundamentals of health and disease and served as a foundation for future patient care [53,63,64]. Students then progressed to pre-clinical dentistry practical courses to link the theory and application of these basic sciences to dentistry. Pre-clinical practical training aims to teach students the core clinical and dental operative skills to ensure students are safe to treat actual patients under supervision [60,65–67]. Once students completed this stage of their studies, they began supervised clinical practice and received theoretical teaching on other oral healthcare topics [68]. Clinical training should provide students with real-life experience in a suitable healthcare setting to acquire practical and professional capabilities to deliver safe and effective patient care [69,70]. This model follows the philosophy of John Dewey and Lave & Wenger, who described the need to balance theoretical and practical learning through participation in authentic "work-based" situations [33,71]. Undergraduate dental programmes were delivered by organising the curriculum into different disciplines or sub-courses, each delivered through lectures and practical sessions and independently assessed [64]. This 'scholar academic' approach to segmenting individual subjects and disciplines leads to the 'problem of classification' whereby teachers often over-emphasise the importance of their discipline, and there are challenges in rationalising and integrating different disciplines [72,73].

The core principles of this hierarchy remain today, and the aims of basic science, as well as pre-clinical and clinical training, are primarily the same. However, there have been fundamental changes to the delivery and structure of healthcare curricula. In medical education, Ronald Harden has been at the forefront of this change since the early 1980s,

when curricula started to move away from the Flexnerian model [50]. The Flexner report, published in 1910, provided ground-breaking information about the state of medical education in the United States and helped shape medical education for many decades worldwide [3]. The Flexner curriculum model is teacher-centred, discipline-led and hospital-oriented [50]. Gies published a similar report with respect to dental education in the United States and Canada [74]. Harden's SPICES model for curriculum development presents two extremes: the traditional Flexnerian model of medical education and a more contemporary student-centred approach [18]. Within this model, Harden described a student-centred, problem-based, integrated, community-based and systematic curriculum and many of these philosophies are now employed in dental education across the world [8,18,25,75–77].

Today, it is thought many undergraduate dental programmes follow at least a partially integrated curriculum, although there is no published data regarding educational structures across Europe. An integrated curriculum combines different disciplines into a domain or theme that is delivered and assessed as one component [78]. Both horizontal and vertical integration have been described in the literature, with vertical integration referring to the integration of concepts throughout a programme of study, with the learning typically increasing in complexity each semester or year [8]. Horizontal integration refers to the process of teaching a topic across multiple themes, which, in many cases, may be delivered by different departments [8]. A combination of horizontal and vertical integration is termed a "spiral curriculum, " as numerous authors describe [79–83]. European guidelines published by an ADEE task force recommend horizontal and vertical integration of sciences and clinical practice [25]. An example of this integration is the increasing popularity of early clinical exposure for dental students in the first years of undergraduate programmes; this allows students to apply theoretical principles to clinical care in real-life, authentic situations [75,83].

In line with a student-centred approach to curriculum delivery, problem-based learning (PBL) and the concept of the self-directed learner have increased in popularity over the

past twenty to thirty years [75]. PBL is an approach to education that was developed by Barrows and Tamblyn in the 1970s [84]. Traditional didactic teaching in medical and dental education focused heavily on knowledge transfer by an expert teacher [85]. It became clear that teaching, learning, and assessment methods that focus on knowledge recall and memory limit a student's ability to think critically and independently and may result in students being unable to apply knowledge to different, unfamiliar situations [85]. Student-centred approaches to teaching and learning, including PBL, are endorsed and adopted by academics around the world due to the importance of forming a dental professional who is a self-directed and lifelong learner [8,25,77]. Common methods of didactic teaching in dentistry include lectures, small group teaching and periods of self-directed study [64]. Moore described the importance of self-directed learning in 1984, where it was stated, *"the first and most important role of a university education is to teach the students to teach themselves"* [86]. The ability of a student to undertake reflective learning cycles and self-directed learning for continuous lifelong development is essential for healthcare professionals. These skills are recognised across numerous UK and European curriculum documents [1,4,8,15,25].

Increasing importance has been placed on dental and medical education to move away from a purely hospital-based setting to include teaching in a primary care or community-based setting [18,75,85,87]. In the UK, 'outreach practices' or primary care placements are becoming more common and combining these with different hospital rotations allows students to experience the profession in a variety of real-life work-based situations, where they can begin to understand the variety of career options, and experience treating different population groups [8,87,88].

To increase transparency and facilitate measurement of the desired graduate abilities, a competency or learning outcomes approach to curriculum design and educational delivery is now popular [4,75]. Competency-based education and a learning outcomes approach are similar to outcome-based education, as described by Harden [2]. Competency- and outcome-based education are related concepts, but some authors have noted a

variation in terminology and interpretation of these terms [35]. All three educational approaches (outcome-based education, competency-based education and a learning outcomes approach) fundamentally relate to a structured education focusing on the graduate's profile at the end of a programme, with dental programmes aiming to produce a “safe beginner”. The principal difference between the approaches relates to writing of learning outcomes that comprise the desired abilities of the dental graduate (outcome-based education, learning outcomes-based approach), whilst competency-based education collates competencies that a student should acquire at the end of a programme of study [89].

Learning outcome approaches to education utilise clear and explicit learning outcomes to inform curriculum content, organisation and teaching, learning and assessment methods [2]. Learning outcomes are *“a series of individual and objective outcomes, with shared ownership between students and staff, designed to facilitate the learning and assessment process.”* [4,20]. Dental education providers are in a challenging and unique position whereby they need to demonstrate that their graduates are fit to practice in the oral healthcare sector. Learning outcomes are favourable in regulated professions due to the focus on the product of education rather than its processes and the ability to map learning outcomes to teaching and assessment [2,66,90].

A learning outcomes approach is becoming more common across Europe as many stakeholders within the European Higher Education Area support this approach to education [1,4,15,91]. Specifically for dental education, the most recent update to ADEE curriculum framework (GED) supports a learning outcomes approach [58,59,61,62]. These documents demonstrate a European consensus on the profile of the Graduating European Dentist, which is presented via learning outcomes. In the United Kingdom, the GDC regulates the profession and outlines the learning outcomes schools must teach and assess [1,15,92]. The current GDC framework, the ‘Safe Practitioner’, was published in 2023 [15].

In summary, the delivery of dental education and the structure of the curriculum today has evolved significantly from the late 20th century models. Whilst most dental

programmes still separate basic sciences, pre-clinical dental studies and comprehensive clinical care, the boundaries between these are much more fluid, moving away from a discipline-based approach to dental education [76]. Current dental curricula are recommended to follow the CELTIC model described by Oliver *et al.* (2008). This model states that a dental curriculum should be competency or learning outcome-based, student-centred, integrated and use explicit and tactical teaching and assessment methods with tailored feedback to support the formation of a lifelong reflective learner with an international outlook.

1.5 The Nature of Learning, Teaching and Assessment in Clinical Dentistry

It is clear from the content discussed so far in this literature review that dental education is both complex and unique. This is not only from a curriculum standpoint; clinical dentistry is challenging for students to learn and for educators to teach. Undergraduate dental students are expected to learn and provide irreversible and invasive treatment for their patients whilst they are still in their clinical infancy [35]. This is compounded by the fact that the practical skills dental students must acquire are unfamiliar and complex to learn [65]. As a result, this is a stressful and demanding environment for students and educators [65,93–95].

Students typically undertake pre-clinical practical courses to minimise the risk of causing harm to patients, as learning and practice occur in a controlled and protected environment [96]. Phantom heads are commonly used in these courses and serve as simulated patients by mimicking a human's upper body and skull. They are equipped with either extracted human or artificial teeth [97]. Pre-clinical practical courses aim to prepare students for supervised clinical practice with real patients. However, challenges in the transition between pre-clinical and clinical education have been reported in the literature [66,68,70,76]. The transition to clinical education is a stressful time for students, where they need to apply their newly acquired skills in an unfamiliar environment and learn additional patient management skills [93,95]. The unique culture of dentistry and undergraduate dental education has been discussed by Chuenjitwongsa [35].

Clinical teaching staff in dental schools often have varied career experiences, and this should be viewed as beneficial in demonstrating the diversity of clinical practice to students. Clinical teaching staff typically include general dental practitioners, educationally trained junior academics, academic/tenure track fellows, senior academics, departmental heads and heads of schools [98]. Dental clinical teachers must assume multiple roles in the clinical learning environment, from simple observation to demonstration, modelling, mentoring, coaching, and supporting/facilitating learning through reflective practice [98–100]. Dentistry is a practical subject, and practical training in clinical environments can be similar to typical apprenticeship models [98]. Clinical educators must attempt to transmit 'tacit' knowledge - knowledge that is difficult to articulate or transfer through words - which adds complexity to clinical teaching [100]. An additional complexity for clinical educators is student feedback and assessment. In dentistry, comprehensive methods of assessment must be in place to control student progression throughout the undergraduate dental programme, this is particularly important when patient care is to be delivered by students [98].

Due to the challenges in teaching clinical dentistry, multiple organisations have described the minimum standards that dental educators should adhere to. Many of these publications consider the quality, content and quality assurance processes related to teaching dentistry. These include the GDC's Standards for Education, COPDEND's Standards for Educators and the Standards for Dental Trainers by the Faculty of Dental Trainers of the Royal College of Surgeons of Edinburgh [92,101,102]. However, more recent work has taken professional standards further by supporting educators in planning their personal teaching development [103]. The importance of quality assurance in dental programmes is recognised in all of these documents, and detailed standards across all European higher education programmes have been published by the European Association for Quality Assurance in Higher Education (ENQA) [104]. ADEE also published recommendations for quality assurance and benchmarking in European dental schools as part of the DentEd project [57]. Universities are now placing more emphasis on the

importance of educational training of clinical staff, with a focus on postgraduate certificates, diplomas, and master's or doctorate-level degrees in education [103].

1.6 The Capabilities of the Graduating Dentist

Upon graduation, a dentist in the United Kingdom and mainland Europe is often referred to as a 'safe beginner' [1,4,92,105]. The terminology is evolving, with 'safe practitioner' used in the most recent GDC curriculum framework update [15]. The term 'entry-level general dentist' has been used in the United States and is a similar concept [75]. The GDC, in the Preparing for Practice document, define a safe beginner as *"a rounded professional who, in addition to being a competent clinician and/ or technician, will have the range of professional skills required to begin working as part of a dental team and be well prepared for independent practice. They will be able to assess their own capabilities and limitations, act within these boundaries and will know when to request support and advice."* [1]. The concept of independent practice does not refer to working in isolation but emphasises that graduating dentists must work within their own competence and scope of practice within an OHP team. The terms "safe beginner" and "safe practitioner" should serve as a minimum standard for graduating dentists, and dental programmes should not leave students unprepared for practice nor stifle excellence beyond this level [4].

With traditional teacher-centred dental education models, skills were the principal unit of measurement for the graduating dentist. Arguably, this reduced dentistry down to procedural tasks [53,77,85]. Focusing on procedures in isolation restricts problem-solving, and most importantly, it neglects to assess the personal qualities that dental programmes should help to shape – a health professional. Most curriculum documents for dental education now describe the knowledge and skills that a dental graduate should possess. These documents also describe the qualities of a health professional, although different terms are used, including behaviours, attitudes, values, or professional attributes [1,8,15,24,77]. These three groups relate to Bloom's learning domains: cognitive (knowledge), affective (attitudes) and psycho-motor (skills) [106].

The GDC describe a competent individual within their definition of a safe beginner. HEIs must ensure that their graduates are competent to begin a post-graduate career in the discipline in question. Competence has been defined across numerous health professional disciplines with slight variation [107–110]. All definitions relate competence to the combination of knowledge, skills and attitudes or values within a context. In dentistry, this context is within a general dental practice and should also consider the ability to work independently [24].

The Dreyfus model of skill acquisition describes five stages of a learner's journey to mastery of a skill; novice, competence, proficiency, expertise and mastery [111]. This model has been adapted to novice, beginner, competent, proficient, expert and has been widely employed in medical and dental education [35,112–114]. A dental student and future dental professional should move through this novice-expert continuum throughout their studies and postgraduate career, with a graduating student fitting in the middle of this continuum at competence. Although, some authors have noted that health professional education should aim to go beyond competence and consider the capability of the graduate [115–117]. The construct of capability is not a higher level on the novice-expert continuum, but competence is one essential part of capability [116,117]. Capability considers the application of competence in changing or unfamiliar environments and values continuous improvement in performance over time [115–117].

The profile of a graduating dentist therefore could be considered as a *capable* professional who can apply their competence (knowledge, skills and attitudes) in both familiar and unfamiliar situations to care for patients in general dental practice whilst continually reflecting on their capabilities and demonstrating a commitment to lifelong learning [6,62].

There are several frameworks at both national and European levels that describe the profile of a graduating dentist. The EU directive 2005/36/EC describes the knowledge and skills that basic dental training (undergraduate dental education) should provide, as seen in Table 2 [36]. This is mandatory for all European dental schools, although it can be

perceived to be outdated due to a failure to describe the desired attitudes and behaviours of graduates.

Table 2 - The knowledge and skills that basic dental training must provide in Europe. Taken from EU Directive 2005/36/EC on the recognition of professional qualifications [36].

Basic dental training shall provide an assurance that the person in question has acquired the following knowledge and skills:
(a) adequate knowledge of the sciences on which dentistry is based and a good understanding of scientific methods, including the principles of measuring biological functions, the evaluation of scientifically established facts and the analysis of data
(b) adequate knowledge of the constitution, physiology and behaviour of healthy and sick persons as well as the influence of the natural and social environment on the state of health of the human being, in so far as these factors affect dentistry
(c) adequate knowledge of the structure and function of the teeth, mouth, jaws and associated tissues, both healthy and diseased, and their relationship to the general state of health and to the physical and social well-being of the patient
(d) adequate knowledge of clinical disciplines and methods, providing the dentist with a coherent picture of anomalies, lesions and diseases of the teeth, mouth, jaws and associated tissues and of preventive, diagnostic and therapeutic dentistry
(e) suitable clinical experience under appropriate supervision. This training shall provide him with the skills necessary for carrying out all activities involving the prevention, diagnosis and treatment of anomalies and diseases of the teeth, mouth, jaws and associated tissues

Task forces within ADEE developed the Profile and Competences for the European Dentist, which was first published in 2005 and subsequently updated in 2009 [24,118]. A significant evolution of these documents occurred in 2017 with the publication of the GED framework [4,58–62]. These documents group the profile of a graduating dentist into four overarching domains: Professionalism, Safe and Effective Clinical Practice, Patient-Centred Care and Dentistry in Society. Within each domain, areas of competence and specific learning outcomes are described. The GED aims to support dental schools in developing their curricula in an outcome-based educational approach – focusing on graduate profiles. However, these guidelines are not mandatory, and it is unclear how widely they are used across Europe.

In the United Kingdom, dental schools must demonstrate adherence to the standards set out by the GDC to satisfy their registration requirements. The GDC provides a curriculum framework in the form of learning outcomes and outlines the standards expected of registered institutions[1,15,92]. The current curriculum framework is titled 'Preparing for Practice' and presents the learning outcomes that each programme should teach and assess. However, a recent update to this framework, titled 'The Safe Practitioner', will be used from 2025 [1,15]. Like the GED framework, Preparing for Practice also groups learning outcomes into domains, these are: clinical, communication, professionalism, management and leadership. The guidance outlined by ADEE and the GDC demonstrates a clear commitment to defining a comprehensive profile of the graduating European dentist and ensuring education providers meet these standards.

The assessment methods throughout a dental programme should be constructively aligned to the learning outcomes and the learning and teaching methods discussed previously [119]. Biggs' concept of 'constructive alignment' encourages transparency and harmony of all curriculum components, particularly between learning outcomes, teaching and learning methods and assessment [119]. To ensure graduates are 'safe practitioner' and have achieved the desired profile, assessments must be accurate, robust, and fair. Many assessments in dentistry are termed 'gatekeeper assessments' – as completing an

assessment permits students to work with increasing levels of responsibility and independence. End-of-programme assessments enable graduates to register with the national regulator [92]. Assessing the whole breadth of the profile of a graduating dentist is not achievable, although assessments should be strategically and longitudinally planned to ensure the learning outcomes have been achieved.

In a similar manner to learning and teaching methods, assessment methods have moved from mass memory recall to the assessment of cognitive processes, moving towards the apex of Miller's pyramid [85,120]. Miller's pyramid is a valuable construct to develop assessment methods, with those at the base of the pyramid typically suitable in the first years of dental programmes. However, assessment methods must move to the "shows" and "does" levels in the clinical years of the programme [120]. Examples of these assessments include objective structured clinical examinations (OSCE), work-based assessments and clinical examinations. This construct also follows Bloom's taxonomy and related learning outcomes, where simpler, lower-order meaningful verbs are used early in courses before higher-level verbs are used later [106].

Whilst dental programmes aspire to assess competence, clinical assessments generally assess performance as a sample of a candidate's overall competency [121]. Assessing clinical dentistry is challenging as the demonstration of learning is complex, certainly for conveying tacit knowledge and clinical attitudes or values [8]. Longitudinal forms of assessment are necessary to assess reflective practice and professional attitudes, and portfolio-based systems can be helpful in this regard [122]. Most dental schools track the number of procedures a student carries out in clinical practice. This target-driven approach is favoured by academics and regulators, with the perception that more is better [77]. Dental students need to gain experience across the whole breadth of the dental profession, and increased practice helps achieve that. However, strategically planned, high-quality educational experiences that incorporate reflection may be preferred to a purely numbers-driven or procedural approach to assessment. This method could allow for longitudinal assessment of student capability rather than performance snapshots.

1.7 Stakeholders of Dental Education

The International Organization for Standardization (ISO), in the ISO 26000 for Social Responsibility, defines a stakeholder as *"an individual or group that has an interest in any decision or activity of an organization"* [123]. Many stakeholders shape the planning and delivery of dental education, and these groups may also be directly affected by changes made to curricula. This highlights the importance of stakeholder consultation when considering changes to dental curricula.

Numerous publications in the dental and medical education literature report on stakeholder opinions of different educational interventions [124–131]. However, none of these studies have provided a clear and comprehensive list of the stakeholders in dental or medical education. Most studies use the term 'key stakeholders', which typically includes students, academics, and clinicians [126-129, 131-134]. Dental education must maintain high standards and be aligned with the goals of the HEI and local healthcare system to meet the oral health needs of the society in which it serves [135]. Bligh, Prideaux and Parsell [19] describe this alignment as *"symbiosis"* between the curriculum, students, health services and local communities. However, additional stakeholders must be considered, and these include:

- Patients as care receivers [25,35,124,128,130,132,134]
- Senior academics, educational decision-makers, deans, postgraduate deaneries [124,126,127,131]
- Policymakers and regulators [124,125,128,131]
- Other healthcare professionals [35,128,130]
- Professional bodies, including dental associations and continental federations [125]
- The health service in the region/country [130]
- Student support services [131]
- Administrators, professional service staff [134]

When exploring the views of medical education stakeholders on teaching cultural diversity, Dogra grouped stakeholders according to their role: policymakers, policy

implementers, education deliverers, researchers, students, and users/patients [124]. Following this methodology, an extensive list of stakeholders in dental education has been defined (Figure 1). All stakeholders in dental education may act as significant drivers or barriers to curriculum development, which will be discussed later in this literature review.

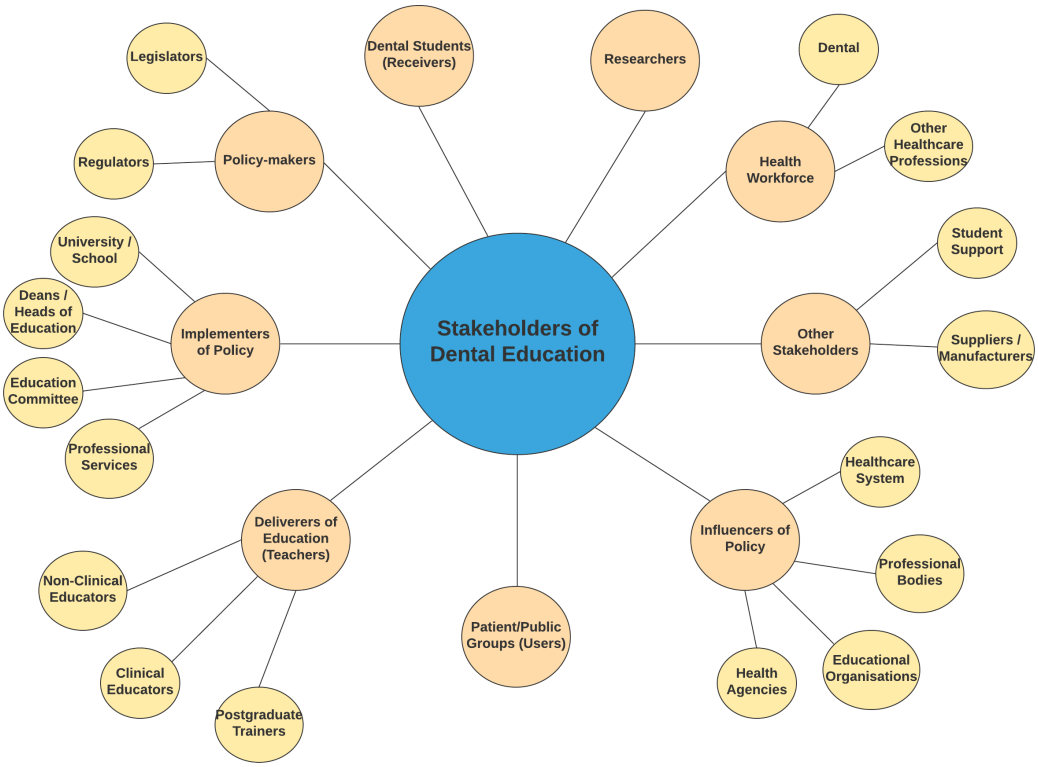

Figure 1 - The stakeholders of dental education

1.8 Convergence and Harmonisation of Dental Education in Europe

The Council of the European Communities acknowledged the need to promote high education standards and mutual recognition of qualifications/diplomas in 1974 [30]. This led to the formation of sectoral directives by the European Economic Community in 1978, which outlined the requirements for different professional qualifications (Medicine, Dentistry, Veterinary Medicine, Architecture) in Europe, with the directive 78/687/EEC being established for dentistry [136]. This presented some basic requirements for a primary dental degree programme and provided a list of subjects to be taught. Whilst these

requirements were lenient and open to interpretation, these were some of the first attempts to promote convergence in dental education across Europe [137]. As discussed earlier, dental education in Europe today is dictated by the EU directive 2013/55/EU, although regrettably, not much has changed [37].

Whilst the directive set out by the European Commission dictates, to a minor extent, dental education for EU member states, the signing of the Bologna declaration in 1999 and the formation of the European Higher Education Area has brought together many more European countries. The signing of the Bologna declaration, by 29 countries at first, established an agreed vision of a future European Higher Education Area. The primary elements of this vision at the time were [138,139]:

- To promote comparability of higher education qualifications from different European countries
- To introduce a clearer, three-cycle system for bachelor, master, and doctorate degrees
- To implement European Credit Transfer System (ECTS) credits
- To facilitate staff, graduate, and student mobility within European countries
- To promote a system of European quality assurance
- To promote a broader European context in higher education

It has long been recognised that substantial variation exists in the organisation and delivery of dental education in Europe. This variation has also been noted at a world level [31]. Shanley *et al.* [137] demonstrated significant differences in the interpretation of the 1978 sectoral directive for dental education. This study utilised a survey in which 30 dental schools responded, and the results demonstrated significant divergence in the methods of assessment and quality assurance by different dental schools across Europe [137]. Differences were also reported in the availability of resources, staff numbers, clinical training places, research and the delivery of patient care. This variation has also been noted in individual courses or modules within programmes of study [66,140,141]. Field *et al.* [66]

also highlighted the significant disparity in regulation and practice across different European countries with regard to pre-clinical dental education.

Concern regarding the findings by Shanley *et al.* [137] led to, in part, the formation of the DentEd Thematic Network Project, which commenced in 1998. The DentEd project aimed to improve the convergence of dental educational practices by promoting high standards and supporting dental schools across Europe through school visitations [32,142]. The project eventually ran for 9 years in three separate phases (termed DentEd, DentEd Evolves, DentEd III) [143]. An output of the DentEd project was the "Development of Professional Competences" [144]. This, along with the signing of the Bologna Agreement, led the ADEE to commission task forces to engage in pan-European consultation to formulate four final outputs:

- Profile and Competences for the European Dentist [118]
- Curriculum structure and the European Credit Transfer System for European dental schools: part I [145]
- Curriculum content, structure and ECTS for European dental schools. Part II: methods of learning and teaching, assessment procedures and performance criteria [146]
- Quality assurance and benchmarking: an approach for European dental schools [57]

As discussed previously, the profile and competences for the European Dentist document was updated in 2010 and curriculum content, structure, learning and assessment in European dental schools in 2011 [24,25]. In 2017, the Profile and Competences for the European Dentist were further updated to mirror contemporaneous educational thinking, created the GED framework [4,58–62].

Although significant efforts have been made to harmonise dental education in Europe, there is a lack of high-quality and robust evidence to determine the current state of dental education in Europe and how widely these documents are adopted. It is of concern that dental education in Europe today is still governed by a limited directive that is open to

wide interpretation. The current directive is not sufficient to guarantee high-quality dental education [32,137]. As European dentists can live and work across Europe, there is a significant possibility that the variation in dental education and clinical training across Europe can lead to inequalities in the dental and oral health workforce and may also impact the safety and quality of European oral healthcare delivery. These concerns were noted by Scott [32], although unfortunately, this may still be the case today.

The extensive geographical nature of the European continent and the significant cultural differences mean that complete convergence or harmonisation of dental education should not be the aim. Dental education should be shaped by the local population's oral health status and needs whilst also considering the local healthcare system [29,30]. Given these significant national and regional differences, as Scott stated, *"it is not surprising that both the process and outcome of dental education vary enormously across the continent"* [32]. European dental schools need a clear minimum standard of education and profile of graduating dentists that is supported by more controlled European legislature that still allows freedom for curriculum developers to shape their programme around local oral health needs and healthcare systems.

As society's and the profession's needs change, the dental curriculum must be responsive, and institutions must ensure that the education they deliver is relevant to future practice. The following section will consider how the dental curriculum develops in response to emerging pressures and challenges.

2. Curriculum Development in Response to Emerging Pressures and Challenges

2.1 The Evolving Dental Curriculum

Previously in this literature review, the curriculum was defined as the cumulation of learning that students must acquire by the end of a programme of study. The learning may be planned, unplanned, formal, informal, or hidden from educators. It relates to an

educational institution's structure, attitude, ethos, and environment and contains all the planned content, learning outcomes, pedagogic techniques, and assessment methods. As educators plan for curricula to evolve, the curriculum in this context usually refers to the formal intended curriculum [40]. Changes to the informal or hidden curriculum are complex, although changes to the intended curriculum will inevitably result in positive or negative impacts on the climate within institutions. The intended curriculum is adaptable and open to development, and therefore, this aspect of the curriculum will be the focus of the remaining part of this section.

The dental curriculum must be responsive to emerging pressures and challenges without diluting its overarching aims and objectives. An undergraduate dental curriculum aims to provide structure, transparency, and ownership of the learning required to reach the minimum level of a safe beginner. There is an absence of published literature to specifically define dental curriculum objectives. However, the following have been deducted from educational literature and scholarship experiences: [4,8,15,18,19,25,40,42,50,57,92]

- Specific to the content of the discipline
- Accessible and communicable
- Sensitive to the needs of students and wider society and resource availability
- Practical and pragmatic
- Deliverable in a specific time frame and with the required resources
- Attainable
- Progressive – continuously building on knowledge
- Measurable
- Sustainable (address the needs of current generations/cohorts to meet emerging changes)
- Flexible (open to further development)

In response to emerging challenges, a curriculum development process must be in place to allow the curriculum to meet these objectives continuously. The intended curriculum should not be fixed; instead, it should evolve to meet the expectations of all stakeholders

and remain fit for purpose [5,8]. To this point, DePaola (2008) stated, "*perhaps the greatest challenge dentistry faces is keeping the curriculum as relevant as possible so that future applications of risk assessment, disease prevention, diagnosis and treatment are allocated sufficient curriculum time to meet changes in patient needs, demands and expectations"*.

2.2 Drivers for Curriculum Change

Numerous internal and external factors may drive changes to dental curricula. The drivers for curriculum change can be broadly categorised into three groups:

- New developments in dentistry
- Educational rationale and innovation
- Changes in society and stakeholder priorities

New developments in dentistry, including technological advancements and changes to evidence-based guidelines or healthcare systems, are critical drivers of curriculum change [5–9,147]. A recent example is the increasing popularity of adhesive dentistry with resin-based composite materials. This has occurred due to significant developments in material science, with resin-based composite presenting several operative and aesthetic benefits. Another reason for this shift is the phase-down of dental amalgam use in clinical dentistry, which was established at the Minamata Convention on Mercury in 2013 [148]. This legally binding treaty aimed to protect human and environmental health from mercury and associated compounds released through dental amalgam placement, removal and disposal. These changes were endorsed by the World Health Organization (WHO) and the World Dental Federation (FDI), which also supported changes to dental curricula by focusing on preventive and minimal intervention models of care compared to historical operative approaches [149,150]. The Minamata Convention was ratified by EU member states in 2017. This led to the development and enforcement of regulation (EU) 217/852, which provided legislation on amalgam disposal and limited the use of dental amalgam in children under 15 years and in pregnant or breastfeeding women [151]. The phase-down of dental amalgam continues to present a significant challenge to the dental profession, with

concerns over finances, clinical time, and inadequate replacement materials [152,153]. In dental education, it seems dental amalgam is used less frequently in dental schools than in primary care. However, dental amalgam teaching still forms a significant part of pre-clinical skills courses around Europe [66,154]. The phase-down of dental amalgam is an example of a significant challenge to the profession. The increased reliance on resin-based materials is a new development within the discipline. These changes to the profession are driving curriculum change in undergraduate dental programmes.

Curriculum development may also be instigated for educational purposes. Unsatisfactory student performance, ineffective educational methods or changes in resource availability are common drivers in this group [5–9,147]. Additionally, feedback from quality assurance processes, either internal or external, should result in curriculum development to optimise educational processes and student learning [8]. A key example of curriculum development that resulted from educational innovation is the shift to student-centred approaches to learning and teaching, including PBL [84].

Changes in society may have a profound impact on the stakeholders of dental education, and these pressures are commonly transmitted to HEIs and dental schools. Governments or regulators may adopt new policies, the needs of society (including our students) may change, and global threats to society may all drive curriculum development in dental education [6,8,9,155]. The COVID-19 pandemic is an example of a strong external challenge that has affected the delivery of dental education worldwide. The immediate emergence of the virus forced education providers to establish new ways to deliver their programmes rapidly. In most dental schools, student clinical education was suspended, and non-clinical teaching was moved online in synchronous or asynchronous formats [156]. Additionally, many assessments were delivered online whilst clinical assessments were either delayed or modified due to the impact of the pandemic on clinical experience [157]. The suspension of clinical training during the pandemic forced educators to reconsider the assessment of clinical competence and the definition of the “safe beginner”. Interestingly, the reduction in clinical experience may have forced educators to incorporate a portfolio

of capability rather than purely focusing on the number of treatments provided. The COVID-19 pandemic is another example of a significant challenge that dental education has faced. It also demonstrates the resilience of dental education providers and the ability to develop curricula rapidly in response to new challenges.

Further examples of drivers that have resulted in changes to dental curricula over the past 30 years include:

New developments dentistry

- Operative changes in cavity preparation due to changes in material science and minimal intervention operative dentistry [154]
- Significant changes to care models including periodontal treatment, endodontics, prosthodontics, paediatric dentistry and oral surgery
- Digital dentistry [158]

Educational rationale and innovation

- Flipped learning
- Remote learning and online methods of assessment
- Virtual reality simulators [67,70,159–161]
- Incorporation of feedback and reflective practice
- Changes in learning trends (social media, different sources of learning)

Pressures from stakeholders

- Psychology and behavioural sciences [162]
- Professionalism [62,105,105,163]
- Ethics [164]
- Inter-professional education [165]
- Environmental sustainability [11,13]

2.3 The Challenges Facing Higher Education Institutions

HEIs and dental schools globally face numerous challenges. According to the literature, these include:

- Financial/economic challenges [31,166–169]
- Reducing number of academic and clinical teaching staff [169–173]
- Challenges in providing suitable clinical experience for students [170,172,174]
- Slow adoption of new technology with limited collaboration and sharing of resources [6,31,168,169]
- Increasing academic and clinical teaching staff workloads [171,175,176]
- Wider university and fiscal pressures [166,172,175]
- New academic and clinical teaching staff recruitment and training [6,98,173,176]
- Variation in healthcare systems and workforce models [6,31,168]
- Changing society and oral health needs of local populations [31,88]
- Limited availability of educational resources, including natural teeth to simulate clinical problem-solving skills [96,172]
- Overloaded curricula [169,172]
- Inequities in student recruitment and selection, particularly those from underrepresented groups [6,169]
- Different educational models across the globe [31]
- Variation in accreditation and licensing of dental professionals [31]
- The changing profile of society [6]
- Divergence between healthcare systems and dental schools [6]

Institutions from across the globe have described these challenges, and they principally serve as barriers to curriculum development. Identifying and confronting barriers is considered a key approach to deliver meaningful change in dental education [177]. Lewin's force-field analysis model outlines the importance of identifying 'driving' and 'restraining' factors to change [178]. Within this model, there is an emphasis on developing a focused action plan to create an imbalance between drivers and barriers to deliver change.

2.4 Curriculum Development Models

Whilst curricula should continue to evolve, structures must be in place to support this process. Some examples of curriculum development models are reported in the literature, which may be helpful to inform educators about this process. Most models focus on extensive curriculum change, or even reform, where there are significant changes to the structure of the curriculum or educational philosophies. Examples include the CELTIC model for dental education and the SPICES and PRISMS models for medical education [8,18,19]. No readily identifiable models explicitly relate to the development of existing curricula without changing the overall programme structure.

Current models in health professional education have stemmed from historical models of curriculum development in general education, principally the objectives and the situational models [179,180]. Tyler's objectives model for curriculum development focuses on establishing educational goals or objectives first and developing education processes around these. In many respects, outcome-based education is a progression of this model [2]. The situational model as described by Skilbeck [180] primarily considers the situation in which the curriculum works, the needs of learners and the impact of internal and external factors.

The core philosophies of these historical models are shared in more recent models of curriculum development in health professional education. Kern's six-step approach to curriculum development is an extensively cited model that was created in the context of medical education [5]. The six steps are:

1. Problem Identification and Needs Assessment
2. Needs Assessment of Targeted Learners
3. Goals and Objectives
4. Educational Strategies
5. Implementation
6. Evaluation and Feedback

Other published models use similar steps to Kern's model or are adaptations applied in different contexts [9,38,50,181]. While Kern's model is still regularly cited in the educational literature, much of the terminology and approaches are outdated, and it also fails to provide guidance on the practical application of each stage. A new model for curriculum development in dental education is needed with particular focus on a learning outcomes-based curriculum and the importance of stakeholder collaboration and regular quality assurance.

Environmental sustainability (ES) is a significant challenge to society, and embedding this topic into the curriculum is urgent. Planetary health and global warming are not new issues, however, awareness of the climate crisis by all sectors has accelerated in recent years. HEIs are now creating ES objectives that their programmes must deliver. Aside from institutional drivers, governmental goals and student demands also support the urgent need to teach ESD [13]. The climate crisis is a key driver for curriculum development in dentistry, and this will be considered in the remainder of this literature review.

3. Environmental Sustainability in Dentistry: An Emerging Challenge

3.1 What is Environmental Sustainability?

Sustainability has been defined by multiple authors and organisations (Table 3). Common themes that permeate across all definitions include harmony between humans and nature and achieving the needs of the present without impacting future generations. ES can be defined as sustainability focusing on the relationship between human activities and the environment. The Articulate glossary defines ES in dental education as *"strategic, holistic and long-term approaches committed to minimising the environmental impact of activities relating to oral healthcare and Oral Health Professional education"* [20].

Table 3 - Definitions of Sustainability

Author	Definition
United States Environmental Protection Agency	*"To create and maintain conditions under which humans and nature can exist in productive harmony and that permit fulfilling social, economic, and other requirements of present and future generations"* [182].
United Nations, Brundtland Commission	*"Meeting the needs of the present without compromising the ability of future generations to meet their own needs"* [17].
Intergovernmental Panel on Climate Change (IPCC)	*"A dynamic process that guarantees the persistence of natural and human systems in an equitable manner"* [183].

Throughout the Earth's existence, the climate has undergone numerous cycles of change. However, scientists have witnessed unprecedented increases in global climate indicators since the 1950s and believe this can only be explained by human activities [184]. The anthropogenic nature of climate change is now firmly established in the scientific literature [185,186]. The standard global climate indicators are global mean surface temperature, atmospheric greenhouse gas concentrations, ocean heat and acid content, global sea levels and sea-ice extent [187]. The Intergovernmental Panel on Climate Change (IPCC) concluded that *"human-induced warming"* had reached approximately one degree Celsius above pre-industrial levels in 2017 [188]. This increase in temperature has been consistent, with each decade becoming increasingly warmer since the 1980s. The levels of greenhouse gases (principally carbon dioxide, methane, and nitrous oxide) within the atmosphere are significantly higher than pre-industrial levels, which is a major contributor to climate change. The increase in atmospheric concentrations of these gases demonstrates the current imbalance between sources (including anthropogenic emissions) and natural uptake through sinks [187]. The rise in greenhouse gases in the atmosphere leads to an increased amount of solar energy entrapment within the Earth

system. This raises global sea temperatures, resulting in higher sea levels and melting of ice caps.

Numerous populations are already feeling the impact of climate change. Future impacts will be more severe and wide-ranging, with significant hazards to nature, human health, animal, plant, and microorganism biodiversity and an increased likelihood of extreme weather events [187,189]. Climate change is a significant threat to global health and impacts the world disproportionately, increasing poverty and inequality further through negative effects on the social determinants of health in high-risk (less wealthy) countries [190]. Climate change will result in direct and indirect health effects, with an increase in infectious diseases, loss of life from extreme weather events, exacerbations of respiratory and cardiovascular diseases due to pollution, water and food shortages and a likely increase in mental illnesses [187,190–192]. These systemic health effects will inevitably result in poorer oral health across the globe [191].

Numerous policies have been adopted to limit climate change and its future impact. The UK government presented one of the first national frameworks to tackle climate change through the Climate Change Act 2008 [193]. At a global level, United Nations members adopted the Paris Agreement in 2015, which aimed to limit the global mean surface temperature increase to 1.5 degrees Celsius above pre-industrial levels [194]. The likelihood of catastrophic outcomes if global temperatures reach 2°C of warming was further clarified in the IPCC's special report in 2018 [188]. By adopting and signing the Paris Agreement, individual nations aim to rapidly reduce greenhouse gas emissions and eventually achieve equity between anthropogenic emissions and natural greenhouse gas uptake, thereby reaching "net-zero" emissions. Alongside this agreement, member states of the United Nations adopted the Sustainable Development Goals (SDGs) in 2015 [195]. These goals consider a range of global strategies to eliminate poverty, reduce inequalities and fight climate change by 2030. SDGs 7 (affordable and clean energy), 12 (responsible consumption and production), 13 (climate action), 14 (life below water) and 15 (life on land) all explicitly relate to protecting planetary health. However, all the goals are closely

aligned, demonstrating the intrinsic link between human and planetary health. Global commitments have taken a step further recently with the Glasgow Climate Pact 2021 established at the COP26 meeting [196]. This agreement strengthened and accelerated the commitments made in the Paris Agreement and focuses on four key strategies: mitigation (reducing emissions), adaptation (supporting those affected by climate change), finance (supporting nations in achieving their goals), and collaboration (cooperation to achieve even greater action). Additionally, countries covering over 90% of the world's GDP agreed to net-zero carbon emissions goals. It is clear that the Earth is reaching a tipping point, and there is a state of planetary emergency that must be managed by immediate and meaningful human action [197].

3.2 Is Dentistry Currently Sustainable?

3.2.1 The Wider Healthcare Sector

The IPCC report from 2018 emphasised that in order to achieve the goals set out by the Paris Agreement, *"rapid, far-reaching and unprecedented changes in all aspects of society"* will be required [188]. Multiple reports by professional bodies and scientific articles have demonstrated that the healthcare sector contributes significantly to both national and global emissions [198–201]. Global healthcare contributes an equivalent of 4.4% to global net emissions; this is similar to the 5th largest country in the world [199]. In high-income countries, the healthcare sector, on average, contributes 5% to the national carbon footprint, similar to the contributions from most national food sectors [198,200]. The healthcare sector contributes to emissions directly through care provision and indirectly from procurement through an unsustainable supply chain [199,201].

As global commitments to mitigate emissions grow, healthcare providers will be required to demonstrate their sustainability strategies and outcomes. In the UK, the National Health Service (NHS) has committed to net-zero emissions by 2040 [12]. In response to the UK Climate Act 2008, the Sustainable Development Unit was established for the NHS to support sustainable practices. Reductions in carbon emissions within NHS England have already begun [198,201]. Significant further inroads are required to mitigate carbon-equivalent

emissions and reduce energy and water usage, pollution, and healthcare waste management [198].

3.2.2 The Oral Healthcare Sector

Dentistry, in line with the general healthcare sector, has a significant environmental impact. To date, two assessments of the carbon footprint of national primary dental care systems have been completed [10,202,203]. The total annual greenhouse gas emissions of a public dental health service in England was estimated at 675,706 tonnes of carbon dioxide equivalent (CO_2-eq) gases [203]. To compare this value to something easier to comprehend, this is equivalent to flying from England to Hong Kong 50,000 times for just one year of primary dental care in one high-income country. Primary dental care contributes around 3-4% to the overall carbon footprint of the general healthcare sector in England and Scotland [203].

It must be noted that the environmental impact of the provision of oral healthcare goes beyond carbon emissions. Oral healthcare also produces significant pollution and waste generation –which is often contaminated and not recyclable and negatively impacts biodiversity [11]. Pollution is an important global issue, with current estimations demonstrating a three-year loss of life expectancy [204]. Most literature in this field reports CO_2-eq emissions exclusively, although research is increasingly being published considering other environmental impacts of dentistry besides emissions.

3.2.3 How Dentistry Impacts the Environment

From the literature, dentistry negatively impacts the environment through [10,11,202,203,205]:

- Travel (staff commuting, patient travel, staff work-related travel)
- Procurement (goods and services including instruments, materials, laboratory items)
- Energy use (electricity and gas)
- Water consumption
- Waste generation and management

Public Health England and the Sustainable Development Unit grouped healthcare CO_2-eq emissions into core emissions (occurring within the healthcare practice), community emissions (occurring outside of the healthcare practice) and supply chain emissions (from goods and services acquired) [203]. Table 4 presents the emissions produced by oral healthcare delivery.

Table 4 - A table of core, community and supply chain emissions in oral healthcare, modified from Public Health England [203].

Core Emissions	**Community Emissions**	**Supply Chain Emissions**
Energy use	Patient travel	Procurement
Waste generation and management	Staff-related travel	Manufacturing and supply of materials, instruments
Staff commuting	Community prevention initiatives	Production of high environmental impact products such as Nitrous Oxide and single-use plastics.
Water consumption		

From previous carbon footprints, the highest proportion of CO_2-eq emissions in dentistry was attributed to travel (65.4%), procurement (19%) and energy (15.3%) [10,203]. Nitrous oxide use, waste and water consumption provide smaller, albeit still significant, contributions. Compared to carbon footprints for the whole healthcare sector (NHS England), travel contributes a greater proportion in the dental sector, whilst the supply chain/procurement presents greater contributions in the general healthcare setting [203]. This is to be expected as dental appointments tend to be shorter and more frequent, requiring repeated episodes of patient travel to and from dental practices.

Travel's contribution to dental carbon emissions is a concern, and this is extenuated by the fact that petrol and diesel-powered cars are also significant pollutants. This has direct health impacts on the local population and impacts quality of life [206]. Waste incineration and anaesthetic gases also contribute to air pollution [11].

The environmental impact of the procurement of goods and services in dentistry is significant, and the true impact is likely to be significantly higher than has been reported in the carbon footprints published so far. The emissions relating to procurement are almost certainly underestimated as limited data is available from companies regarding manufacturing processes and related emissions [205]. The substantial reliance on single-use plastics (SUPs), further accelerated during the COVID-19 pandemic, is not sustainable as the plastics used are currently unsuitable for recycling [207]. This leads to a wasteful linear economy from sourcing raw materials, manufacturing, packing and distribution, clinical use, and waste collection and disposal [11].

3.2.4 The Impact of Dental Procedures on the Environment

There is limited high-quality evidence to provide conclusive statements on the environmental impact of different dental procedures. Different research methodologies have been employed in the existing literature, thus presenting challenges in performing an accurate analysis. From the research completed to date, dental examinations and preventive items of care (professional tooth cleaning, fluoride varnish, fissure sealants) present the lowest individual carbon footprints [10,203,208].

The placement of direct restorations, regardless of material choice, has been reported as having a moderate contribution to the carbon footprint of primary dental care [10,203]. However, it is essential to note that the research methodologies to estimate the carbon footprint of direct restorations primarily measured time and energy use, and there are no studies that directly compare the CO_2-eq emissions associated with these different materials throughout their life cycle, nor do they consider the impact of the materials on pollution and biodiversity. Smith *et al.* [209] completed a cradle-to-gate life cycle assessment of dental amalgam, resin-based composite and glass-ionomer cement and demonstrated

significant environmental impacts for all materials, with dental amalgam producing the highest impact for material use and resin-based composite for energy use and packaging.

Two studies have considered the environmental impact of root canal treatment, but the methodologies employed were vastly different [10,210]. These studies suggest that endodontic treatment presents a moderate-to-high environmental impact due to the use of numerous single-use instruments, various medicaments, and the often-prolonged nature of treatment, with multiple visits required.

Fixed and removable prosthodontic procedures are estimated to have the highest carbon footprint as they are resource-intensive in terms of time, number of appointments, transport of laboratory work, and material use. The provision of nitrous oxide, a greenhouse gas, for inhalation sedation amounts to the highest emissions per item of care [10]. It is important to reiterate that most of the published literature focuses on carbon emissions, but dental procedures also have other significant environmental impacts, including pollution and ecotoxicity [211].

The environmental impact of different dental procedures varies in total emissions released (typically measured in mass of carbon dioxide equivalent CO_2-eq) and in the profile of contributions. It has been reported that travel contributes a lower proportion of emissions for the more resource-intensive procedures, whilst procurement of all instruments and materials and energy use become the major contributors [203].

Examinations and preventive treatment are the most sustainable items of care that OHPs provide, and this may give insight into potential strategies to make oral healthcare more environmentally sustainable at a population level. However, these are also the most performed procedures in primary dental care, and the cumulative impact of dental examinations is the single biggest contributor to emissions in oral healthcare [208]. Therefore, strategies must also be employed to make these procedures more sustainable and cost-effective.

3.2.5 Research Methods to Assess Environmental Impact

Research is key to developing a comprehensive knowledge base of current practice [212]. The environmental impact of specific practices, procedures or products can be measured in several ways, including carbon footprinting, life cycle assessment, resource consumption (energy, water, petrol/diesel, materials), waste generation, air quality changes and impact on biodiversity [213,214]. The carbon footprint is a term used to describe the greenhouse gas emissions produced by individuals, products, organisations, or activities. Wiedmann and Minx [215] defined the carbon footprint as *"a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product"*. Whilst this is a recognisable term, measuring environmental impact goes beyond measuring greenhouse gas emissions [216].

Life Cycle Assessment (LCA) is a research methodology used to assess environmental impact. LCA can measure other environmental impact indicators aside from greenhouse gas emissions, including pollution, waste generation and impact on biodiversity. Two common approaches to LCA are:

- Process-based LCA
- Environmental Input-Output Analysis LCA

Process-based LCA measures emissions attributed to the stages of a process or product's life cycle [217,218]. Complete LCAs consider the environmental impact of a product across its whole life cycle, usually from sourcing raw materials to disposal or from "cradle to grave" [219]. Partial LCAs assess the impact of a product from one part of its life cycle. A common type of partial LCA is termed 'cradle-to-gate', which measures impacts from raw material extraction and manufacturing before distribution. Process-based LCAs can give accurate estimates of well-defined processes or products but may make comparisons between different products challenging if similar methodologies are not employed [203]. Additionally, this methodology relies on accurate data from manufacturers, which is not always available.

Environmental input-output LCA equates economic data and expenditures from various systems to carbon emissions [220]. This methodology makes generic assumptions and is thereby less precise at a small scale but is much more efficient for making comparisons across large datasets. Studies in dentistry commonly combine both types in a hybrid approach to achieve complementary benefits [10,202]. Various standards for planning, completing and reporting LCAs have been published [221–223].

3.2.6 Conflict with Regulations, Policy, and the Healthcare System

Regulations and policies are imperative to set standards of high-quality oral healthcare and protect patients from harm. Unfortunately, many regulatory bodies produce policies without concern for the environmental impact of the behaviours they are mandating. The most pertinent issues currently relate to infection prevention control measures and SUPs, whereby legislation to protect patients is employed without considering the evidence base or the environmental impact. Duane *et al.* [224] critically reviewed the environmental impact of the decontamination regulations set out in the HTM 01-05 in the UK and demonstrated significant issues regarding existing practices that are not evidence-based nor environmentally conscious. Single-use infection prevention control measures have been proven to produce higher environmental impact than other reusable solutions [225]. In some countries, reusable options may be permitted, but often, the language used in policy documents is confusing, which may make dentists select the option that is deemed safest and easiest – the single-use option [226]. This conflict with policy is recognised across several publications [11,207,227–229]. It is also recognised that ES is often not a key priority in the structure of NHS dentistry in the UK, where the focus, aside from patient safety, is on financial wellbeing and units of dental activity [230].

3.2.7 Rationale for Environmentally Sustainable Dentistry

The fact that dentistry, which aims to promote health and prevent oral disease, is a significant contributor to climate change is concerning [11]. A shift to an environmentally sustainable healthcare model is essential as it is driven by public demand, increasing environmental commitments by healthcare providers and the ethical code of OHPs.

Providing oral healthcare in a sustainable manner is not only good for the environment. Sustainable care is high quality care that is good for the local population and financially viable. Sustainable healthcare, aside from protecting the planet, presents a win-win situation with the following benefits:

- Economic sustainability [231]
- Improvements in health and disease prevention [231,232]
- Increased patient responsibility to maintain health [232]

All stakeholders in dentistry must identify the ethical responsibility to deliver a more environmentally sustainable healthcare system. The need to conceptualise and deliver strategies to make oral healthcare more sustainable is clear.

3.3 Strategic Environmental Concepts to Achieve Change in the Profession

Some changes to practice are immediately achievable, whilst others require time to embed and develop into common practice. This section will focus on strategic environmental concepts to achieve long-lasting environmentally sustainable changes to the profession. Immediately achievable strategies will be discussed in the subsequent section.

3.3.1 Raise Awareness

Raising awareness of the urgent requirement to deliver ESD is the cornerstone of the overarching strategy. Whilst public awareness of the need to become more sustainable in everyday life is increasing, there is an apparent lower awareness of how OHPs should alter their daily practice [16,233]. All strategies should aim to increase public and professional awareness of the impact of oral healthcare on the environment to support environmentally sustainable change.

3.3.2 Integrate and Normalise the Subject of Environmental Sustainability

To raise awareness and meet the goals set at global, national, societal, and professional levels, the subject of ES should be normalised and completely integrated into daily life

[190,207]. This will ultimately require a change of mindsets, and ways to achieve this vary from informal conversations to more sophisticated strategies, including embedding the topic of ES in educational curricula, media, marketing, and research outputs. An interesting example is noted by Duane *et al.* [10] who suggested that clinical software should include sustainability reporting alongside financial data. This could promote a shift in "value for money" whereby practitioners also consider the "value of carbon" [10,234]. This simple example of normalising the subject of ES in oral healthcare is one strategy that may begin to recalibrate the attitudes of many OHPs and associated stakeholders.

3.3.3 Environmental Citizenship

Environmental policies and regulations should not be the only method to drive sustainable change. To fully embed the concept and practice of environmentally sustainable dentistry a change of mindset is required. This includes changing deeply embedded attitudes and increasing the value of environmental resources. Currently, there is a disparity between people's environmental behaviours at work and home [11,207,211,235]. One must consider why this is the case? A lack of policy, overwhelming barriers to sustainable practices and individual attitudes will likely restrict environmentally sustainable behaviour in the workplace. In addition to this, research has demonstrated that whilst people tend to rate environmental issues as important, people tend to rate their health as more important and therefore healthcare professionals may forget or demote environmental issues in their working life [236,237]. Whilst all of the above points may be true, this section will consider attitudinal and behaviour change.

Fiscal incentives are commonly used in environmental policy to change the behaviour of society to deliver environmental benefits. These measures can be very effective; a popular example is the plastic bag charge, which has successfully reduced plastic bag use in stores. However, as argued by Dobson [238], fiscal incentives are less likely to deliver changes in attitudes. This is because they use extrinsic motivation to change behaviour, which can undermine intrinsic motivation to act. Intrinsic motivation is more effective at changing behaviour and sustaining long-term changes than extrinsic motivation [239]. This is a concern

because, without fiscal measures in place, many in society may not perform environmentally favourable behaviours because these concepts are not embedded in the attitudes and values of society. A different view is to focus on a stronger, more deeply rooted, attitudinal approach to ES with the idea that environmentally sustainable behaviour will naturally result from these attitudes. This is the concept of environmental citizenship – whereby a citizen's behaviour is influenced by an underlying attitude that is informed by a value of the common good [238]. The environmental citizen will inevitably use environmental resources and produce emissions and waste; however, it is the responsibility of the citizen to minimise their environmental footprint. There should be a sense of duty and justice. Braito *et al.* [240] provide evidence to support this theory by demonstrating the strong link between human and environmental relationships and subsequent behaviour.

Two approaches to behaviour change have been considered: fiscal incentives and environmental citizenship. Both approaches are viable, and a key focus should be on raising awareness across society and providing education on environmental citizenship. This is important because win-win scenarios through fiscal incentives are not always possible, achievable, or effective. At some point society will need to make decisions about the actions they take [238].

One should also consider the diversity of humans. Although unproven, it is likely that parts of our society already demonstrate environmentally sustainable attitudes and behaviours, others have intentions but feel helpless, and some people are not concerned about environmental issues. Thus, various strategies to achieve attitudinal (and ideally resultant behaviour) change are required, including widespread education, information campaigns, role models, and fiscal incentives [190,241].

How can the concept of environmental citizenship be incorporated into oral healthcare to promote change? Achieving sustainable change will require significant social, regulatory, and attitudinal changes to the profession. According to Klöckner [242], interventions to change environmentally sustainable behaviour require attitude campaigns, normalising

the topic and environmental behaviour, and providing clarity through policy on how to behave in a sustainable way. The author would argue that environmental citizenship is the single most important principle; a change in attitudes will mean citizens and professionals will routinely seek environmentally sustainable solutions in all aspects of life.

3.3.4 Reduce, Reuse, Recycle and Rethink

The term reduce, reuse and recycle (3 R's) has been around for a number of years and has been a key slogan in awareness campaigning for ES. The 3 R's are frequently cited in the environmental literature, although recently, an additional "R" – rethink - has been included in some reports [16]. Existing policies and regulations in oral healthcare make implementing the 4 R's challenging [211,230]. This is particularly evident with the regular use of SUPs in oral healthcare, which leads to a wasteful linear economy, as discussed previously in this literature review. Additionally, these SUPs are most commonly segregated as clinical waste and disposed of via deep landfill or incineration, which has further significant environmental consequences [211]. The underlying principle of the 4 R's is to shift to a circular economy where materials can be reused, recycled and renewed [205]. Currently, a complete switch to a circular economy is impossible in oral healthcare [226]. However, the 4 R's still present fundamental values and opportunities across the full breadth of oral healthcare to make significant environmentally sustainable changes.

Due to the challenges associated with oral healthcare, employing a reductionist approach will have the greatest impact in reducing the environmental footprint of the sector [16,211,243,244]. Reducing all aspects of oral healthcare from treatment demand, travel, energy and water consumption, procurement and waste would present the single greatest contribution to an environmentally sustainable oral healthcare service. This will stem from improved prevention of oral diseases and the provision of high-quality oral healthcare [211]. Additional opportunities include reducing waste through appropriate segregation, procuring items with reduced packaging and utilising digital technology to decrease material use [16,245].

For oral healthcare, reuse is likely the most challenging element of the 4R's. However, It is possible to reuse appropriately disinfected equipment and instruments, with studies demonstrating that reusable items are associated with lower emissions than single-use items [225,246,247]. Other strategies for "reuse" include removing single use rinsing cups, surgical gowns, face shields and sterilisation pouches and replacing them with reusable alternatives [16].

Recycling the contaminated SUPs used in oral healthcare is challenging with current equipment and policies. However, emerging technology in mechanical and chemical recycling is encouraging [16]. Non-contaminated waste presents potential avenues for recycling, and this should be promoted to reduce the consumption of natural resources and waste. Segregation and recycling of sterilisation pouches and other packaging and domestic waste should be achievable with staff engagement and well-developed policies.

A rethink across the whole profession and widespread stakeholder engagement is essential to establish a circular economy within oral healthcare.

3.3.5 The Importance of Oral Disease Prevention and High-Quality Oral Healthcare

Reducing treatment need through effective oral disease prevention and high-quality interventions is the foundation of environmentally sustainable oral healthcare [16,207,212,226,232]. Prevention is of fundamental importance in all aspects of oral healthcare and helps to reduce oral health inequalities. Patients who are at low risk for developing oral diseases utilise significantly fewer oral health services and thereby have lower environmental impacts [244]. Considering the largely preventable nature of these diseases, strategies to reduce oral disease risk are essential [207]. Additionally, when operative interventions are required, they should be evidence-based, high-quality, and durable [16]. Prevention of oral diseases will reduce carbon emissions and other environmental impact indicators through fewer patient visits and interventions, resulting in less travel, material procurement and clinical waste [212].

Whilst preventive items of care present lower carbon emissions than other operative interventions, it is essential to gain further insight into the specific impacts of different preventive products [10,16,205]. The cumulative effect of preventive items of care on the environment will still be significant, although they must be balanced with the positive oral health outcomes and the likelihood of reducing emissions through reduced interventions across a patient's life [16]. Research in this area has commenced, with LCAs on community caries prevention providing interesting results that can be compared to clinical effectiveness data [248–250]. Future research should contribute to the evidence-base for both clinical effectiveness and environmental impact of procedures or materials. This would provide policymakers and OHPs with helpful information to support evidence-based and environmentally sustainable care delivery.

The FDI Sustainability Framework Infographic demonstrates the importance of preventive and high-quality patient-centred care for environmentally sustainable oral healthcare [207]. This is presented across four domains: preventive care, operative care, integrated care and ownership of care. In addition to the value of preventive and high-quality operative care, the authors reaffirm the importance of patient ownership of care due to the largely preventable nature of oral diseases [207].

Future oral healthcare must prioritise prevention, and this should be achieved by engaging all stakeholders to deliver environmentally sustainable and high-quality care to reduce the need for future interventions. To support this, healthcare systems and providers must value and incentivise preventive care [205,226].

3.4 Areas of Focus to Deliver the Strategic Environmental Concepts

Action and innovation are required to embed the strategic environmental concepts (raising awareness, normalising ES, environmental citizenship, the 4Rs, and the value of high-quality preventive and operative oral health care) into the profession. From the literature, these include education, policy and regulations, stakeholder engagement, and research.

3.4.1 Education

A key focus should be educating all stakeholders to increase awareness and to promote changes in attitudes towards ES [226,234]. While some awareness within the profession may be increasing, this is not widespread. There is also no clear strategy to support meaningful, practical action concerning ES education [11,251].

The lack of education relating to ES across the profession is widely recognised [11]. There have been many calls to embed ES in undergraduate dental curricula [205,212,226,229,233,234,252–254]. Dental schools are in a key strategic position to embed ES attitudes and behaviours within the professional persona of their graduates. This will increase the likelihood of future OHPs valuing ES and practising environmentally sustainable oral healthcare. ADEE has established ES as a key priority by forming a special interest group with regular meetings. This has led to the publication of a consensus paper that establishes the need to embed ES dental curricula and provides overarching principles to achieve this [13]. Looking into the future, graduating OHPs must hold values of environmental citizenship to question existing unsustainable practices, campaign for change and be the voices of the future [13].

There have been fewer considerations regarding educating the existing profession – whom must not be forgotten [212,252]. Strategies to change the long-standing values and practices of the current workforce will inevitably present significant challenges; however, establishing high-quality CPD programmes on ES in oral healthcare and including the topic at conferences or annual meetings present valuable opportunities [254]. Support from professional bodies, including guidance, educational networks and incentives, can also help in normalising the topic of ES [227]. The topic of sustainability could even be part of mandatory CPD requirements.

Patients can also be educated on sustainable healthcare practices. Advice regarding environmentally sustainable oral health regimes can be incorporated into routine oral hygiene advice and should form part of informed consent when planning care [16,212]. Patients can also be made aware of the benefits of reduced travelling and waste by

grouping appointments and attending the practice with other family members. Providing small reminders, such as recycling opportunities for used oral health products and recommending turning off the tap during toothbrushing are also appropriate.

3.4.2 Policy and Regulations

The challenges and conflicts with existing policies and regulations have been discussed in this literature review. Policy must be reviewed to facilitate the provision of environmentally sustainable dentistry and prohibit certain unsustainable practices. Policy drives behaviour change, which is required across the whole sector to achieve sustainability goals [226]. Policies and regulations also provide accountability, which is essential across all stakeholders [190].

Although there is a need to raise professional awareness, there is also an evident lack of policy and guidance to support and facilitate environmentally sustainable practices [234,255]. This is a significant issue as many OHPs who want to practice more sustainably don't always have the tools to do so. The perceived disengagement between the ability to provide safe and effective oral healthcare whilst behaving in an environmentally sustainable manner must be dispelled, and regulators and professional bodies must work together to provide OHPs with pragmatic and clearly worded policies to support ES practices [16,207,226]. The environmental impact of clinical materials and procedures should be included alongside the evidence for clinical efficacy within policy documents [216].

A hybrid 'top-down and bottom-up' approach to policy development is needed within dentistry [205]. Top-down policy approaches rely on expert input from people who are often distant from the place in which the regulations will be applied [256]. External experts need to be included to ensure environmental concepts and actions are appropriately applied. However, exclusively utilising this approach can disengage local users of policy. In many cases, the policy may not be applicable locally due to oversight of the realities of these contexts [257]. Including all local stakeholders (OHPs, all other members of the dental team and the public) in a bottom-up approach to policy is essential to ensure policies are clear and applicable in local contexts [205,235,257]. This is also necessary to empower people and

drive sustainable change. A bottom-up approach to policy is closely related to the concept of environmental citizenship – empowering OHPs to take ownership of environmental issues and supporting a strong attitudinal approach to the subject.

There have been specific calls in the literature to provide new policy documents for infection prevention control and to mandate transparent reporting of the environmental impact of manufacturers within the supply chain [16,205]. Additionally, decision-makers at all levels (including those commissioning dental services) should be aware of the environmental impact of the profession and how their decisions can support (and inhibit) change [254].

3.4.3 Stakeholder Engagement

The complexity of ES in oral healthcare requires all stakeholders to work collaboratively. An approach that does not consider the situation and input of other stakeholders will be fundamentally flawed. The vast array of stakeholders in dentistry has been considered earlier in this literature review. With a particular focus on ES, engaging with staff, patients and supply chain organisations are common stakeholders discussed in the literature [207,213,234].

Staff and patients should be involved in the change process to better understand the cause and ensure buy-in for the planned changes [234]. Baird *et al.* [258] demonstrated that patients have positive attitudes toward sustainable oral healthcare and are willing to compromise on the time, convenience, and durability of the treatment offered. Staff members should be empowered to take on new responsibilities and provide valuable suggestions to improve sustainability within their workplace [213].

Stakeholders within the supply chain, including manufacturers, distributors, and procurement departments within large institutions, must also be incorporated into the planning of environmentally sustainable dentistry [205,207]. This will make the supply chain more sustainable throughout the product's life cycle. A recent joint stakeholder consensus

statement presents promising progress on this front, with many important industrial stakeholders committing to urgent action [16].

3.4.4 Research

Research is fundamental to increase the knowledge base and to drive sustainable change in dentistry. The complex psychosocial impact of climate change means that accurate and carefully worded reporting of research findings is critical [190]. It is not enough to suggest that one procedure or material should be avoided when the environmental impact of alternative options has not been measured [208]. Carefully worded guidance, supported by high-quality evidence on clinical efficacy and environmental impact, is an absolute necessity to facilitate sustainable practice. Achieving this will require expertise, research excellence, education and appropriate funding [205].

High-quality research is required to further understand the environmental impact of existing dental practice and any alternative procedures or materials [16,199,203,205,228,255]. This baseline knowledge must be established before planning change or new goals within the profession [212]. High-quality LCA with standardised and transparent methodologies are required to facilitate comparison between different studies and settings [216]. It is crucial to appropriately design LCA's to account for the complexities of the supply chain, the delivery and packaging of materials, the complexity of the procedure, and any additional items used [212]. There is an urgent need to identify hot spots in current practice and to compare different materials and interventions [16].

Innovation, research, and development are needed to develop new "green" dental products and to establish innovative ways to enable OHPs to apply the principles of the 4Rs [205,234]. This may include the development of new chemicals that produce zero or more environmentally sustainable waste and novel ways of recycling contaminated plastic waste.

Additional attention must be paid to social science, including quantitative and qualitative research methodologies, to understand the mindsets of dental stakeholders [16,205]. This

could provide insight into stakeholders' perceived drivers and barriers and may allow for greater collaboration to establish unified and aligned regulatory frameworks. Stakeholder engagement (including manufacturers, distributors, regulators, professional bodies, students, OHPs and patients) in research may also enable more accurate and complete LCA analysis of dental materials and procedures [212]. Engaging with stakeholders and supporting them in contributing to this core knowledge is of significant value.

3.5 Cross-cutting Strategies for Environmentally Sustainable Dentistry

Immediately achievable strategies to make oral healthcare more environmentally sustainable can be divided into two groups:

- Cross-cutting strategies to reduce environmental impact.
- Focused strategies that target defined emission contributors (e.g. travel, procurement).

Cross-cutting strategies reduce environmental impact across multiple domains. Strategic themes within this group include increasing efficiency, utilising technology, reduce, reuse, recycling and waste, staff initiatives, and increasing biodiversity. Table 5 provides examples of environmentally sustainable practices within these themes.

Table 5 - Cross-cutting strategies to deliver more environmentally sustainable oral healthcare according to identified themes.

Strategic Theme	Examples of Environmentally Sustainable Actions
Increasing efficiency	Use motion sensors and meters to limit energy and water use [213,227,252] Invest in energy saving and energy efficient equipment [213,224,227] Ensure appliances (dishwasher, autoclaves) are full prior to use [208,224]
Utilising technology	Switch to digital radiography (reducing radiation and chemical use) [227,252,259,260]

	Adopt digital dentistry practices including intra-oral scanning and CAD-CAM (reducing impression and gypsum waste and travel) [16,227,254,260] Utilise remote clinical consultations [261] 26/02/2025 22:20:00
Reduce	Reduce paper use (electronic notes, history taking, double sided printing) [227,260] Reduce sterile packaging, tissue and glove use where possible [228] Reduce SUPs where possible [212,224] Reduce nitrous oxide conscious sedation and use capture technology [16,213,234] Only prescribe medications when absolutely required [213] Reduce travel emissions– recommend active travel or public transport [206,213] Reduce packaging by buying in bulk and combining orders [213,234,252,260] Reduce ecotoxic chemical use by using environmentally more sustainable, disinfectants, and steam sterilisation [208,224,234,252,260]
Reuse	Switch to reusable clothing, personal protective equipment items and sterilisation pouches [208,252,260] Switch to reusable dental instruments (impression trays, suction tips) [208,260] Use washable patient drinking cups and staff room kitchenware [252,260]
Recycling and waste	Appropriate disposal of amalgam waste [16,227,252,259] Select biodegradable alternatives where possible [227] Segregate waste correctly (clinical, domestic, recyclable) [230,262]

Staff initiatives	Establish a sustainability action group in the healthcare setting, fostering a strong attitudinal approach to ES [212] Designate sustainability and waste management leads within practices [16] Informal/formal discussion regarding existing setting's processes [228] Staff training [16]
Increasing biodiversity	Establish outdoor green spaces [263] Reduce lawn mowing of grassed areas [263] Avoid tarmac or concrete and place more porous ground material [11,263] Place insect friendly and native plants and trees [11,263] Introduce green roofs or walls [263]

3.6 Focused Strategies for Environmentally Sustainable Dentistry

3.6.1 Reducing the Environmental Impact of Travel in Dentistry

As discussed previously, travel is the greatest contributor to emissions in primary dental care in England and Scotland [10,202]. The high emissions are predominantly related to patient travel and staff commuting. In addition to carbon emissions, travel can increase air pollution, which negatively impacts health and reduces the quality of life of local populations [206].

Specific recommendations in the literature to reduce the environmental impact of travel within dentistry include:

- Promote and incentivise active travel (walking, running, cycling) wherever possible [16,206,234,245,254]
- Use vehicles that reduce fossil fuel use (e.g. electric vehicles charged with renewable energy) [16,206,234,245,254]

- Use public transport or car sharing [16,206,234]
- Select local manufacturers, distributors and waste services to reduce travel [234]
- Utilise technology to reduce appointments and associated travel (tele dentistry, digital dentistry) [16,206,212,234,254]
- Combine appointments with family members to reduce travel [206,245,254]
- Advise longer appointments to reduce number of appointments and associated travel [206]
- Community prevention initiatives to reduce individual travel [206,248–250]
- Recall appointments determined by clinical need/disease risk [206,254]

3.6.2 Reducing the Environmental Impact of Dental Procurement

The need for environmental policy and high-quality research is particularly evident when considering strategies to reduce the environmental impact of procurement in dentistry. Based on previous carbon modelling, dental procurement is the second largest contributor to emissions [10,202]. However, it can be hypothesised that this is a significant underestimation due to a lack of detailed data across the entire supply chain. Conducting and publishing high-quality research across all elements of dental practice, including the supply chain, is the only way practitioners can make evidence-based choices on environmentally sustainable practices. Procurement is not just limited to a single dental practice; the supply chain commences with raw material sourcing and then progresses to manufacturing, distribution and transport [212]. There are many stakeholders in dental procurement, all of whom have their individual agendas, pressures and policies. Collaboration amongst stakeholder is necessary to establish policies and protocols to mitigate the environment impact of the supply chain [212].

The most important role of OHPs in reducing the impact of procurement is to engage with stakeholders across the whole supply chain to support environmentally sustainable practices [16,199,212,243]. OHPs can influence and challenge manufacturers, distributors and waste collectors, resulting in more environmentally sustainable practices [212,243]. It is likely that when OHPs begin to question the environmental practices of stakeholders within the

supply chain and purchase more environmentally sustainable products, the whole sector will change their practice [243].

In addition to engaging with stakeholders across the supply chain, other recommendations for reducing the environmental impact of dental procurement include:

- Effective stock management, including regular auditing to limit waste [16,243,245]
- Choose more environmentally sustainable materials, instruments, chemical and sundries where high-quality evidence exists [243,245]
- Increase efficiency and coordination with suppliers to reduce travel and consider locally produced items [16,228]
- Consolidate orders, reducing frequency of transport and packaging [243]
- Reuse packaging associated with procurement [243]

3.6.3 Conserving Energy and Water Consumption in Dentistry

It has been demonstrated that dentistry utilises significant amounts of energy (natural gas and electricity) and water [10,202]. This leads to a depletion of natural resources, and as most electricity is generated from fossil fuel combustion, it produces high CO2-eq emissions and air pollution [264]. Renewable sources of energy, including wind and solar power, can be used to generate electricity and have minimal environmental impacts. The switch to renewable energy is supported in the literature [199,252,264]. A key barrier is pricing, with renewable energy costing much more than other means of electricity generation. However, as demand and production increases, it can be assumed that renewable energy will become more accessible [264]. Healthcare organisations may also consider generating their own renewable energy using solar panels, heat pumps or biomass heating [16,205,245,264]. Whilst governmental price incentives have been rolled out in the UK, cost and energy storage remain a concern.

Considering the barriers to renewable energy use today, attention must be paid to efficient energy consumption whilst using fossil fuels and natural gas [234,264]. New is not always better – evidence suggests that older-style clinics appear to be more energy efficient than

many new, large, and open-planned clinics [10,202]. Focused strategies to preserve energy and water consumption have been recommended in the literature:

- Ensure existing appliances and equipment are functioning efficiently and consider energy ratings when purchasing new items [264]
- Utilise technology to increase energy and water efficiency (smart meters, automated thermostats, motion detectors, timers, low-flow water devices) [245,252,264]
- Install energy-efficient lighting (LED bulbs, dimming, daylight harvesting) [205,245,264]
- Limit the use of air conditioning and consider natural ventilation and shading [264]
- Efficient use of space to limit energy waste through heating or air conditioning use [245,264]
- Ensure effective insulation is in place to reduce energy use [264]
- Efficient use of energy-intensive appliances (washer disinfectors, autoclaves) by using them only when full [264]
- Carry out energy and water audits to monitor overall consumption and efficiency [16,234]

3.6.4 Reducing the Environmental Impact of Waste Disposal in Dentistry

Dental waste is complex and typically composed of infectious, hazardous, domestic, recyclable, and food waste [260,262]. Ways to manage waste include placing it in landfills, incineration, recycling, or reusing it for other means (such as composting or anaerobic digestion) [260]. Infectious waste is usually disposed of via incineration, whilst domestic waste goes to landfill [16,262]. Incineration is more suitable than landfill for infectious waste to mitigate issues with ecotoxicity. However, it requires large amounts of energy, releases significant carbon emissions and produces pollution [16,260]. Waste production from dental practice has been increasing, including a major acceleration during the COVID-19 pandemic, with large amounts of SUPs used in every clinical encounter [260,265]. An average of 21 SUPs are reportedly used for routine operative dental procedures [265]. An average of 25 different types of items have been found in waste bags, with tissues most common, followed by gloves and sterile bags [230]. A recent LCA by Almutairi *et al.* [266] demonstrated the

significant environmental impact of the personal protective equipment items used during the COVID-19 pandemic compared to standard cross-infection control measures and reusable items. This again reiterates the point that healthcare interventions must be evaluated with the "triple bottom line" – where clinical effectiveness, cost-effectiveness and ES are considered [249].

The previously discussed strategic concept of reduce, reuse, recycle and rethink are essential to reduce the environmental impact of dental waste [260]. Reduction is the most important strategy [16,230,262]. It is clear that due to the complex materials used in dentistry and the contaminated nature of clinical waste, complete implementation of the 4Rs is impossible in the current climate [11]. This further illustrates the need for innovation, research and education across all sectors [212].

Another key strategy to reduce harmful waste is through correct segregation [262]. There have been conflicting reports in the literature regarding OHP adherence to correct waste segregation, however these studies were all limited in size [227,230,267]. Segregation is a legal requirement for infectious waste and for hazardous waste such as amalgam. However, correct segregation of recyclable and domestic waste provides additional health, environmental and financial benefits [16,230,262]. Incineration of infectious waste is expensive; therefore, correct segregation will reduce costs for the practice and the harmful environmental effects of incineration [16,245].

Whilst regulations are in place for clinical waste disposal in the UK, most focus on the disposal of infectious and hazardous waste [260]. Legislation heavily focuses on the safe disposal of dental amalgam, which has been demonstrated to have significant environmental impacts through mercury leakage into wastewater from dental practices [212,259]. Whilst amalgam use is decreasing, the mercury will still be released from the cremation of cadavers for decades to come [211]. However, attention must be paid to other commonly used materials in dental practice, including resin-based composites, ceramics, and impression materials [205,212,230]. The harmful environmental potential of microparticles of resin-based composites and associated eluted monomers has been demonstrated [268].

Further research and legal guidance is required regarding the disposal of these materials [230].

Additional strategies to reduce waste in dentistry include:

- Reduce materials/equipment purchases or select alternatives (distributors/items with reduced packaging, more environmentally sustainable products) [245,262,269]
- Select reusable instruments and materials where possible [262]
- Recycling waste that is not contaminated and is recyclable (for example, separating sterile bags and recycling in paper and plastic waste) [230]
- Employ good practice (e.g. high-quality clinical care to reduce material waste and avoid repeat procedures, seal materials to minimise evaporation) [234,269]
- Perform regular audits for waste management [16,262]
- Facilitate access to recycling by providing segregated waste bins for staff and patients [245]
- Utilise technology in dentistry to reduce waste generation [269]
- Identify transparent waste disposal services that may be employing novel technology to recycle waste [212,243]
- Segregate and dispose of food and pharmaceutical waste appropriately [16,245,262]
- Recycle unused or unwanted items [245]

3.7 Drivers and Barriers to Environmentally Sustainable Change in Dentistry

Many drivers and barriers to sustainable change in dentistry have been discussed throughout this literature review. Drivers include the increasing importance of ES for stakeholders and an apparent professional and public interest in ES in healthcare. Key barriers that have been identified include a lack of awareness, knowledge, and education, as well as limited policies to support or facilitate sustainable change in a clinical setting.

A further list of the drivers and barriers to environmentally sustainable change in dentistry, can be seen Table 6 and 7 below.

Table 6 - Drivers to environmentally sustainable change in oral healthcare.

Drivers to environmentally sustainable change in oral healthcare
Increasing importance of ES on the agendas of stakeholders [13,14,16]
Professional interest in environmentally sustainable practices [251,270]
Increasing public interest and commitment to ES [271]
A need and desire to maintain and enhance professional reputations with environmentally sustainable practices [16,214]
ES is marketable and is likely to increase interest and opportunities for practices [214,254]
Environmentally sustainable dentistry is likely to lead to a reduction in practice expenses [235]
Some governmental incentives to support environmentally sustainable change [16]

Table 7 – Barriers to environmentally sustainable change in oral healthcare.

Barriers to environmentally sustainable change in oral healthcare
Evidence of limited professional awareness and knowledge of existing unsustainable practices [11,233,262]
Little evidence of widespread education of students and OHPs on environmentally sustainable dentistry [11,251,262]
No policies to support and facilitate environmentally sustainable dentistry [234,255]

Limited existing infrastructure to support widespread environmentally sustainable practice (e.g. local procurement, environmentally sustainable waste disposal, cycle paths etc.) [11,206,243,262]
High costs of more environmentally sustainable options (renewable energy, electric vehicles, recycled paper) [243]

4. Environmental Sustainability in Undergraduate Dental Education

4.1 Support for Environmental Sustainability in Dental Education

There is clear support to embed ES in undergraduate dental and OHP education. This was highlighted in a previous section of this literature review, which considered education as a key area of focus for delivering environmentally sustainable change in dentistry [205,212,226,229,233,234,252,253]. It is increasingly clear that ES is high on the agenda of HEIs [13,272]. This support will empower dental schools to embed ES within their curricula. Support from professional bodies further strengthens the drive to teach this subject [13,14]. Numerous surveys have demonstrated significant support from dental students for ES, although response rates were limited in most studies [251,270,273,274]. Three surveys also uncovered positive attitudes from staff/faculty toward ES, although limited knowledge and strategies to embed ES in the curriculum were also raised as a concern [251,273,274].

4.2 Is Environmental Sustainability Currently Taught in Undergraduate Dental Education?

It is still to be determined if the support to embed ES in undergraduate dental and OHP education has resulted in demonstrable action. Medical education appears to be further ahead on its agenda, with multiple publications of learning outcomes included in curriculum documents worldwide [275–277]. However, a recent global survey demonstrated

limited uptake of ES teaching in medical education [278]. There is little evidence to give insight into existing practices in dental and OHP education, and therefore, the teaching of ES is anticipated to be limited. Most existing practices will likely be bottom-up approaches – initiatives from individual educators within institutions [13,279]. Top-down approaches, including new standards and policies from regulators and institutions, are required to initiate widespread incorporation of ES in dental curricula [279]. Considering the limited evidence base in dental and OHP education, the following sections will combine literature from all health professional disciplines. Whilst there are intricate differences across the various healthcare professions, a discussion of existing ES educational initiatives is necessary due to the novelty of the subject and the scarcity of evidence. Programme structures, regulations, and professional profiles are similar across all healthcare professionals, and therefore, it is reasonable to assume existing practices can be shared amongst disciplines.

4.3 Barriers to Teaching Environmental Sustainability in Undergraduate Dental Education

While the need to integrate ES into dental education is clear, multiple barriers must be addressed to implement this change. ES is a new and unfamiliar concept to most educators and students, which may cause anxiety [280]. Staff and student engagement and leadership are essential to comprehensively integrate this concept into curricula [13,205,276].

Barriers to teaching ES in healthcare include:

- A perceived lack of knowledge and expertise to teach ES in healthcare [251,272–274,281–285]
- Time constraints due to the already overloaded curriculum [272–274,279,284,285]
- A lack of practical guidance to integrate this teaching across the length of programmes [272,279,282]
- Lack of learning resources for educators and students [251,272–274]
- Perceived challenges in assessing ES concepts [272,283]

- Resistance from some stakeholders regarding the relevance of ES in dental education [282,285]
- Conflicting priorities as healthcare providers [279]
- Perceived limited evidence base for ESD [285]

4.4 Key Principles to Embed Environmental Sustainability in Undergraduate Dental Education

All approaches to embed ES in the undergraduate dental curriculum must overcome the reported barriers. The European Commission has used the term 'Whole Institution Approach' as a key strategy in their Education for Environmental Sustainability policy document [286]. This demonstrates the importance of ES being incorporated into all aspects of an institution. The following principles to support embedding ES in health professional curricula have been developed from the literature and will be discussed further below:

- ES as a threshold concept
- Longitudinal integration of ES concepts in the existing curriculum
- Constructive alignment of learning outcomes, teaching activities and assessment
- Staff development, co-creation, and collaboration
- Evaluation, flexibility, and development of ES curricula

4.4.1 Environmental Sustainability as a Threshold Concept

To manage challenges in student learning and the overloaded curriculum, it has been recommended to identify threshold concepts to better direct finite resources to essential learning or topics that students find challenging [287]. Meyer and Land first described threshold concepts as: *"A portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding or interpreting, or viewing something without which the learner cannot progress"* [288]. The Articulate glossary of OHP education terms defines threshold concepts as: *"A topic within a curriculum that, when understood, results in fundamental changes in perception and practise of other parts of the subject/discipline"* [20]. Multiple characteristics of threshold

concepts have been identified; however, two appear to be imperative across numerous publications; the concept must be *transformative* and *irreversible* [287–290]. Threshold concepts must be *transformative* in that, once understood, there is a clear shift in perception, attitudes, or values. Threshold concepts should also be *irreversible,* meaning they are unlikely to be changed or forgotten.

The education of clinical health professionals combines two types of knowledge: experiential and conceptual [291]. Experiential knowledge is derived from experiences, in this case, sequential clinical experiences throughout a dental programme. Conceptual knowledge, often abstract and context-independent, is often acquired through didactic means, such as lectures. A disparity between these two knowledge systems creates the "theory-practice" gap, as described by Rolfe [292]. Relating the two knowledge structures in a complementary manner with the identification and focus on threshold concepts within curricula has been recommended to reduce the impact of this gap [289,293].

ES fits the definition of a threshold concept due to its transformative and irreversible nature. The first step in incorporating ES into curricula is identifying its importance and directing sufficient resources to achieve the aims of the curriculum development initiative.

4.4.2 Longitudinal Integration of Environmental Sustainability Concepts in the Existing Curriculum

Complex constructs such as ES should be longitudinally integrated across the length of the undergraduate dental curriculum [13]. This principle has also been emphasised in the medical education literature [272,276,285,294–296]. ES concepts should be introduced early in the dental curriculum and reinforced throughout the programme with increasing levels of complexity. The importance and urgency of planetary health means ES must be a lens through which all other components of dental education and oral healthcare are viewed [297]. It is likely that a standalone course for ES at one point in the curriculum will not reinforce learning of this topic in the context of the whole discipline and may be more difficult to arrange within the constraints of the dental curriculum. Longitudinal integration allows the existing curriculum structure to remain intact, and new concepts

can be weaved or infused into existing learning, teaching, and assessment processes. This approach can overcome the reported barrier of overloaded curricula, and distributing content across the length of the programme can enable all staff to feel more engaged in curriculum development.

Curricula need to be fit for purpose on a local level. A *'think globally, act locally'* approach reiterates that modifying or updating existing curricula with ES concepts is sensible [276]. Longitudinal embedding of ES concepts also ensures that the content is relevant to the stage of the programme and should allow opportunities for practical learning in clinical environments [272]. Linking ES and professional practice is essential to demonstrate the relevance of ES in the future of dentistry [282,295]. The importance of connecting the relevance of ES to clinical practice has been demonstrated in a participatory action research project of eight medical schools in the UK [280]. Practical learning through clinical cases that incorporate ES principles may be an appropriate way to establish this link.

4.4.3 Constructive Alignment of Learning Outcomes, Teaching Activities and Assessment

Learning ES concepts in undergraduate dental curricula should occur at three levels: knowledge acquisition, skill development and attitudinal learning [282]. ES learning outcomes should be clear, explicit and measurable across these three levels and methods of teaching and assessment must be constructively aligned [119]. Learning outcomes for ES need to be developed as no published examples of such work exist. The writing of learning outcomes should be explicit to describe the desired change in the learner. Additionally, these should be introduced sensibly into the existing curriculum in a longitudinal manner [65].

Knowledge-focused teaching and assessment methods are well established. They are important for establishing a baseline understanding of climate change, planetary health, the environmental impact of oral healthcare, and environmentally sustainable strategies [276,282]. Existing learning activities can be infused with knowledge of the environmental impact of procedures delivered across all disciplines of oral healthcare and more environmentally sustainable alternatives.

A change of thinking around existing skill development in dental curricula is necessary. Viewing the discipline through the 'sustainability lens' will incorporate this concept into everyday thinking [297]. Clinical skills teaching should foster strong ES attitudes to take ownership of the materials used and reduce waste, resulting in concurrent environmental, educational, and financial benefits. Another example is learning communication skills to deliver oral health advice to patients, which is part of the existing curriculum. This teaching should be tweaked to incorporate the additional, complementary benefits of oral disease prevention for the environment and the environmental impact of different preventive regimes.

Attitudinal or value-based learning are not new concepts in dental education, as similar constructs such as professionalism and ethics are embedded in dental curricula [62,298]. Attitudinal learning for ES is essential as our students will be drivers of change for the future [294]. Students are increasingly aware of their duty to protect the environment. Still, these attitudes need to be fostered at a greater scale to develop professionals who are environmentally accountable and prepared to be advocates for future reform [251,270,273,274]. Education systems must equip students with an understanding of the problem and how change occurs, as well as developing communication and advocacy skills [282]. In psychological research, the relationship between attitudes and behaviours is complex. Positive attitudes do not always result in positive behaviours, as many factors can affect and deter one's actions. Behavioural scientists have sought to identify the critical factors and formulate theories that explain why attitudes do not always predict behaviour. An example is the Theory of Planned Behaviour [299]. Blake [300] described a similar construct as the value-action gap, which focuses on environmental policy. Both concepts propose that positive attitudes are the foundation of predicted behaviour. However, social norms, perceived behavioural control or practicality of the behaviours play a significant role in the outcome. Promoting specific attitudes (e.g. towards ESD) demonstrates the strongest predictor of behaviour – which again supports the need for relating ES teaching to professional practice [301]. This is not to say that holding general positive attitudes to ES is

irrelevant or cannot form part of the curriculum – positive spillover and consistency in attitudes have been recognised in the literature [258,302].

Assessment promotes learning, and methods must be aligned to the level of knowledge, as specified in the defined learning outcomes, and follow Bloom's taxonomy and Miller's pyramid of competency [106,120]. Assessment for learning (formative assessment) and of learning (summative assessment) are appropriate at different stages of courses or programmes. For the levels of knowledge acquisition and skill development, existing assessment methods may be adapted without any significant changes, this may include written papers, practical assessments, and case-based discussions [276]. Assessment of attitudes relating to ESD is more challenging and may require novel assessment methods [272,295]. Longitudinal assessment grounded in reflective practice may be appropriate for assessing ES attitudes [276,282]. This could include reflective portfolios incorporating elements of ES alongside other clinical considerations.

4.4.4 Staff Development, Co-Creation and Collaboration

The perceived lack of local expertise to teach ES is a reported barrier in the literature. This can be overcome by raising awareness through staff development activities and collaborating and co-creating with staff, students and external departments.

Staff development will form an integral part of the rollout of ES in the curriculum. Staff development sessions should not aim to make expert teachers, they should raise awareness and foster a teamworking environment. It is anticipated that much of the teaching relating to ES and planetary health can be delivered by non-experts who *'learn alongside the learners'* for this complex and emerging issue [272,295]. Staff development should focus on fundamental concepts such as climate change, the impact of climate change on health, how healthcare contributes to climate change, environmentally sustainable strategies for care delivery and educational strategies to embed ES in the curriculum [303,304].

Co-creation of resources between staff and students is particularly relevant for this emerging topic and could be incorporated into assessment. ES is a trans-disciplinary issue, and sharing resources amongst similar programmes or institutions would significantly reduce workload, avoid duplication, and potentially improve the quality of teaching [272,282,296].

4.4.5 Evaluation and Development of ES Curricula

Interventions to embed ES in the curriculum must be evaluated *post-hoc* in order to identify areas of strengths and weaknesses. Curricula must be open to development, and early ES educational interventions will look different as time progresses [272]. Evaluation can take multiple forms, including internal and external quality assurance processes [305]. An example of a student-led evaluation process is the Planetary Health Report Card that was launched in medical education in 2019 [284]. This tool grades the university's performance according to various planetary health metrics, including the incorporation of ES teaching in the curriculum. A version for dental and OHP education is currently being developed.

4.5 Examples of Environmental Sustainability Educational Interventions

There are limited published examples of practice that incorporate ES in healthcare curricula. From the small pool of research in this area, examples of ES teaching tend to be small-scale interventions within specific disciplines. Straßer et al. [306] delivered a seminar that was combined with multiple climate-related tasks. Pre- and post-tests were completed using a standardised questionnaire, which demonstrated significant increases in ES-related knowledge but revealed that environmental attitudes and awareness had not significantly changed. The findings of this small-scale study illustrate the importance of longitudinal integration of ES concepts. Kligler *et al.* [307] developed the Climate Change Curriculum Infusion Project (CCCIP), which integrates ES into existing medical curricula. Students and staff co-created lecture slides to embed in existing lectures in pre-clinical courses. Student evaluations demonstrated positive views towards the relevance of the content and the knowledge gained relating to climate change and health. The tools used to measure the impact of this intervention are limited, and the response rates were also

low. However, the methodology of embedding content in the curriculum is of interest. A multi-centre national review of UK medical courses by Bevan *et al.* [296] revealed a wide disparity in ES teaching. Although the evidence is very limited, this study highlighted that an approach with dedicated lectures early in the programme with further material interspersed throughout the curriculum currently appears the most effective.

5. Summary

This literature review addresses the research question, *'How does the undergraduate dental curriculum evolve to incorporate new concepts, such as environmental sustainability?'*

The regulation and delivery of dental education across Europe is complex, with a directive that is minimally descriptive and open to interpretation. Limited published data exists to compare curriculum practices across Europe, and an outdated report suggests substantial variation [137]. National regulators, such as the GDC in the UK, set additional standards for education providers at a national level. Further research is required to understand the current state of dental education across Europe and to uncover core curriculum practices.

Dental curricula must be flexible to equip their students with the necessary knowledge, skills, and attitudes to meet the demands of the profession in the future. ES is an example of a curriculum disruptor that requires immediate and profound changes to dental programmes. Multiple professional bodies have established the need to embed ES in dental and OHP education [13,15]. A curriculum development process must be in place to enable these changes to occur with minimal disruption and without impacting the overall aims of the programme.

Oral healthcare delivery is unsustainable, with significant environmental impacts resulting from staff and patient travel, procurement of materials, instruments, equipment, waste generation, and energy and water use [10,202]. The profession must significantly change to achieve environmental goals at national and international levels. The key areas of focus are education, policy and regulations, stakeholder engagement, and research.

There is limited evidence of existing teaching practices for ES in dental education. Evidence from similar attitudinal constructs, such as professionalism, suggests that ES should be longitudinally integrated into the curriculum, and opportunities for applied practical learning should be provided. The co-creation of resources with students and external departments should be considered to improve the quality of education and reduce workload. Drivers and barriers to this change must be studied to provide solutions.

This literature review has identified numerous knowledge gaps concerning dental education and ES. A novel educational research project that seeks to attain this knowledge must consider the following as part of its methodology:

- Review and investigate the state of dental education in Europe with regard to programme details and curriculum structure.
- Identify existing educational practices, barriers and drivers to embedding ES in dental education.
- Engage in extensive stakeholder development to formulate strategies and learning outcomes to embed ES within the constraints of an existing curriculum.
- Develop evidence-based content for educators to teach ES.
- Evaluate the effectiveness of various teaching interventions on student awareness, knowledge and attitudes toward ESD.
- Develop a new model for curriculum development that incorporates contemporary educational terminology and practices.

Chapter III - Aims and Objectives of the Research

Aim

To develop, implement and evaluate a curriculum development model to embed environmental sustainability in undergraduate dental education.

Objectives

- To explore the current state of dental education in Europe and articulate common curriculum practices.
- To identify current teaching practice of environmental sustainability in undergraduate dental education and identify key barriers to change.
- To engage with key stakeholders to create and develop strategies to embed environmental sustainability in the undergraduate dental curriculum.
- To implement and evaluate the effectiveness of a range of learning and teaching events used to embed environmental sustainability across the length of the undergraduate dental curriculum.
- To develop a contemporaneous model for curriculum development that demonstrates a strategy to embed new topics into an existing dental curriculum.

Proposed Research Plan

To achieve the aims and objectives of this project, multiple studies have been planned across three proposed 'research areas':

1. The current state of dental education in Europe.
2. How can environmental sustainability be embedded into the undergraduate dental curriculum?
3. Evaluation of the impact of environmental sustainability in the undergraduate dental curriculum.

The current state of dental education in Europe

Multiple methodologies have been planned to answer this research question. This will commence with a scoping review to explore the current reporting of dental and oral health professional (OHP) education in Europe. This will be followed by a stakeholder-agreed vision for OHP education for the future and the development of a glossary of terms for OHP education. A survey-based methodology will be used to collect data regarding the current state of dental and OHP education in Europe.

How can ES be embedded into the undergraduate dental curriculum?

Current educational practices for environmental sustainability (ES) in dental schools will be explored through multiple surveys across different geographic regions. Strategies to embed ES in the existing dental curriculum will be developed through consensus-based approaches to develop learning outcomes and teaching and assessment methods for ES. Focus groups will be used to explore staff and student opinions regarding opportunities to embed ES within an existing curriculum. Student opinions regarding the relevance of ES to their undergraduate programmes will be explored through a survey. Evidence-based and subject-specific content will be created through a literature review and stakeholder consultation to support educators in teaching ES.

Evaluation of the impact of ES in the undergraduate dental curriculum

The research completed in the previous two research areas will inform a plan to embed ES within an existing curriculum. The plan will be implemented and evaluated using a survey to assess the impact of the teaching interventions on awareness, attitudes and knowledge of environmental sustainability in dentistry.

Figure 2 provides an overview of the thesis structure.

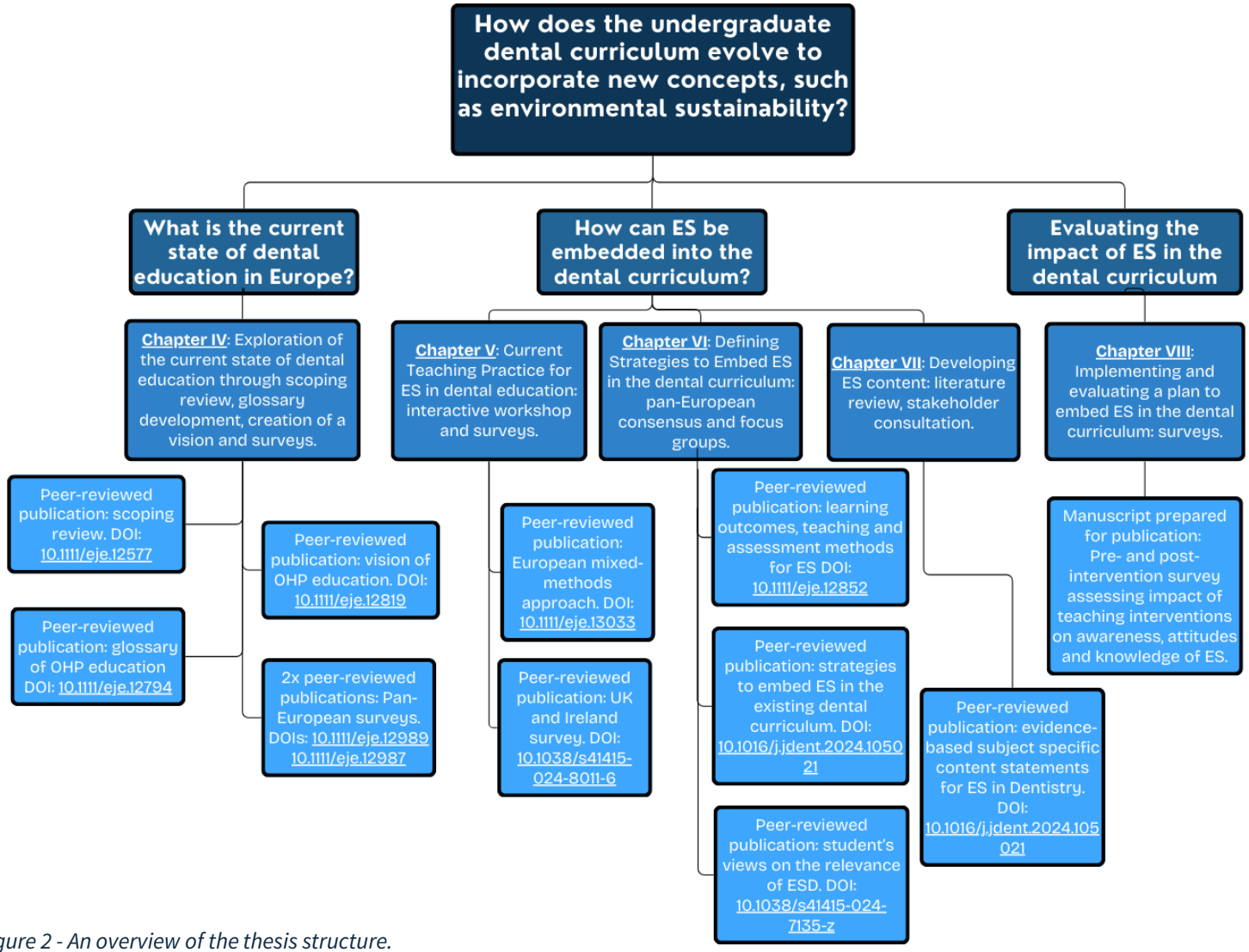

Figure 2 - An overview of the thesis structure.

Chapter IV – The Current State of Dental Education Across Europe

Overview

A mixed methods approach was employed to explore the current state of dental and oral health professional (OHP) education across Europe and to develop a stakeholder-agreed vision for the future. The individual methods that contributed to this chapter included a scoping review, a qualitative consultation, glossary development and a survey. The included peer-reviewed manuscripts contribute to this chapter [308–312]:

> ***Dixon J**, Manzanares-Cespedes C, Davies J, Vital S, Gerber G, Paganelli C, et al. O-HEALTH-EDU: A scoping review on the reporting of oral health professional education in Europe. European Journal of Dental Education. 2021;25(1):56–77.*
>
> *Field J, **Dixon J**, Davies J, Quinn B, Murphy D, Vital S, et al. O-Health-Edu: A vision for oral health professional education in Europe. European Journal of Dental Education. 2023 May;27(2):382–7.*
>
> *Davies JR, Field J, **Dixon J**, Manzanares-Cespedes MC, Vital S, Paganelli C, et al. ARTICULATE: A European glossary of terms used in oral health professional education. European Journal of Dental Education. 2023;27(2):209–22.*
>
> ***Dixon J**, Field J, Vital S, van Harten M, Roger-Leroi V, Davies J, et al. O-HEALTH-EDU: A viewpoint into the current state of Oral Health Professional education in Europe: Part 1: Programme-level data. European Journal of Dental Education. 2024 May 1;28(2):591–606.*
>
> ***Dixon J**, Tubert-Jeannin S, Davies J, van Harten M, Roger-Leroi V, Vital S, et al. O-Health-Edu: A viewpoint into the current state of oral health professional education*

in Europe: Part 2: Curriculum structure, facilities, staffing and quality assurance. European Journal of Dental Education. 2024 May 1;28(2):607–20.

Candidate Contribution

The PhD candidate was invited to represent the School of Clinical Dentistry, University of Sheffield, in an Erasmus + funded research project titled 'O-Health-Edu'. This arose due to the candidate's previous leadership and involvement in pan-European educational research outputs and activities. The project was managed by the Association for Dental Education in Europe (ADEE) and included nine university partners from across Europe. The PhD candidate drove the project's conceptualisation and helped shape the aims: to understand the current state of dental and OHP education in Europe and create a strategic vision for the future. To gain insight into the current state of dental education, the PhD candidate conceptualised two approaches, developing an evidence-base through a scoping review and creating an online data hub to collect data regarding OHP educational practices across Europe via a survey-based approach. These approaches were intrinsically linked with two additional tasks: developing a vision for OHP education for 2040 and creating a glossary of educational terms to provide clarity of language for all survey terms. All five manuscripts result from extensive work by all authors and O-Health-Edu project partners. For the three principal investigator first-author publications, the PhD candidate led conceptualisation, methodology design, investigation, data curation and analysis and research write-up. The PhD candidate provided significant contributions to the conceptualisation, methodology design, investigation, stakeholder consultation, data curation and analysis and research write-up for the two co-authored publications that were led by Professor James Field (Cardiff University) and Professor Julia Davies (Malmö University) respectively. Summaries and the full-text documents for each publication are presented in the following text.

A Scoping Review on the Reporting of Oral Health Professional Education in Europe

Introduction

Differences in European dental education have the potential to profoundly affect the population's oral health. The O-Health-Edu project aimed to collect data regarding the current practices of European dental schools through a survey-based approach. Due to limited previous research in the form of literature reviews and exploratory investigations, a literature review was required to provide evidence-based recommendations for future survey investigations and establish a baseline understanding of current practices. A scoping review was selected due to its flexibility in a previously unexplored area [313,314].

Aim

The scoping review aims to investigate how dental and OHP education is reported across Europe.

Methodology

The PRISMA and Arksey & O'Malley frameworks guided the methodological approach. A search strategy that included published literature searches (from scientific and educational databases), internet searches and further hand-searching of documents on stakeholder web pages was developed. A consultation was undertaken with key stakeholders to ensure the search strategy was fit for purpose and reduce the potential for missed information. Identified sources were screened by two authors (JD, JF), and approved sources were charted using a standardised form. Repeat searches were performed once the authors became more familiar with the literature, as proposed by Arksey & O'Malley [314]. Through descriptive statistics, quantitative analysis was used for the year of publication, journal, study type, and location reported. Due to the largely qualitative nature of the included sources for 'subject matter reported', this area was analysed through thematic analysis [315].

Results

The searches produced 508 sources in total, with 405 excluded due to not reporting the topic within the research question. After additional handsearching and removal of duplications, 85 sources were included in the final review. The average year of publication was 2007, and most of the published literature emanated from dental education journals. Surveys were the most common methodology used for reporting OHP education practices. The thematic analysis of the subject matter generated four themes: dental education at a programme level, dental education at a discipline level, other OHP education and postgraduate education and continuous professional development.

Relevance

This scoping review demonstrated that the reporting of dental and OHP education in Europe is limited. There are many examples of published guidelines and curricula in the European context, but how these are applied in local contexts needs to be clarified. The scoping review established a need for a data collection process on programme and curriculum practices across Europe. This need is emphasised by an inability to state the number of dental schools within the continent accurately. This scoping review presented a valuable starting point to gain an understanding of the state of dental and OHP education in Europe. This work will inform future surveys in order to establish a needs assessment and situational analysis for future curriculum development initiatives.

Received: 9 March 2020 | Revised: 15 June 2020 | Accepted: 13 July 2020

DOI: 10.1111/eje.12577

ORIGINAL ARTICLE

WILEY

O-HEALTH-EDU: A scoping review on the reporting of oral health professional education in Europe

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Funding information
Agence Erasmus+, Grant/Award Number: 2019-1-FR01-KA203-062894

Abstract

Introduction: The variability in oral health professional education is likely to impact on the management of oral health needs across Europe. This scoping review forms the initial part of a larger EU-funded collaborative Erasmus + project, 'O-Health-Edu'. The aim of this scoping review is to investigate how oral health professional education in Europe is reported.

Methods: The PRISMA and Arksey & O'Malley methodological frameworks for scoping reviews were used to guide reviewers in answering the research question "How is oral health professional education reported in Europe?". The search strategy encompassed published literature searches, internet searches and further searching of relevant documents from educational organisations, regulators and professional bodies. Once the search strategy was developed, it was sent to key stakeholders for consultation. Sources were reviewed by two authors (JD, JF) and included in the review if they reported on oral health professional education in Europe.

Results: A total of 508 sources were retrieved from all of the searches. A total of 405 sources were excluded as they did not report on the topic of interest, leaving 103 sources that reported on oral health professional education in Europe. Handsearching the references of published sources lead to a further 41 sources being screened, of which, 15 were included. In total, 33 duplications were removed and the final number of included sources was 85. The average year of publication for the included sources was 2007, with sources most commonly published in journals dedicated to dental education. Surveys represented the most common form of reporting. From the data obtained, four broad themes of reporting were evident: dental education at a programme level, dental education at a discipline level, other oral health professional education, and postgraduate education and continuous professional development.

Conclusion: The reporting of dental and oral health professional education in Europe is limited. Whilst there are many useful documents that provide guidelines on dental

education, there is limited knowledge on how education is implemented and delivered. There is a greater need for comprehensive educationally driven programme-level data on oral health professional education across Europe.

KEYWORDS
dental education, dental hygienists, dentists, oral health professionals, professional education, review

1 | INTRODUCTION

Historically, 'dental education' has focused on the education of dentists. More recently, however, the term is used to encompass a wider range of professionals, also known as 'dental care professionals' or 'oral health professionals'. It is difficult to obtain a unanimously agreed definition of these terms due to the different regulation of oral health professionals across the continent. However, the terms tend to encompass the complete range of dental professionals including dentists, hygienists, therapists, nurses and clinical dental technicians.

Basic dental training (a primary degree in dentistry or dental surgery) in the EU is regulated by the European directive 2005/36/EC on the recognition of professional qualifications. This states that "*initial dental training must be for at least 5 years' study, with the equivalent ECTS credits, and must consist of at least 5,000 hours of full-time theoretical and practical training provided in a university or in a higher institute providing training recognised as being of an equivalent level or under the supervision of a university*".[1] There is no similar recognised directive for other oral health professionals such as dental hygienists or dental therapists[2]; instead, this is often managed nationally by individual regulators.

The variability of oral health professional (OHP) education, training and clinical experience may be explained by the superficial guidance present in the directive—and therefore is open to broad interpretation by dental educators across Europe. The European directive informs educators regarding the length and type of training that should be provided, but provides little guidance by way of curriculum content and programme delivery.

1.1 | Harmonising dental education within the European Higher Education Area

Whilst the World Health Organization (WHO) defines the European Region as comprising "*53 countries, covering a vast geographical region from the Atlantic to the Pacific ocean*",[3] the European Union (EU) is defined as "*a unique economic and political union between 27 EU countries that together cover much of the continent*".[4] The European Economic Area (EEA) is a political link between the EU and three European Free Trade Association (EFTA) countries (Iceland, Lichtenstein, Norway). In contrast, the European Higher Education Area (EHEA) is an international collaboration between 48 European countries. It was formed to follow up the signing of the Bologna Process in 1999, which placed the mutual recognition of higher education qualifications into European law and therefore facilitated the movement of students and professionals across higher education institutions in Europe.[5]

In 1998, the European Union's Directorate for Education and Culture funded the DentEd Thematic Network Project (TNP) which aimed to harmonise dental education through promoting higher standards in dental education in an ever-widening EU.[6] The Association for Dental Education in Europe (ADEE) embodies dental schools across Europe and has formed a large network of dental educators. ADEE has supported or acted as a medium for much of the recent work aiming to harmonise dental education through their annual meetings, taskforces and special interest groups. The DentEd project led ADEE to commission three task forces to focus on the delivery of European dental education. This culminated in the development and publication of the Graduating European Dentist in 2017, which provides recommendations for best academic practice in dental education.[7]

This variability in oral health professional education is of concern, because current EU legislation permits European graduates to practice dentistry across Europe through mutual recognition of their qualifications. These important migration flows of students and dentists across Europe may bring together professionals with differing experiences and skill sets. This, in turn, may lead to inequities in the density and competence of oral health professionals—with some places underserved and others overcrowded. This is likely to impact on the management of oral health needs across Europe.

Considering the extensive nature of oral health professional education and the lack of previous reviews in the area, a scoping review has been selected as the appropriate methodological approach. A scoping review is of particular benefit when the initial research question is broad, allowing exploration of the literature that underpins the research question. In turn, this facilitates further more focused reviews (including systematic reviews).[8,9]

This scoping review forms the initial part of a larger EU-funded collaborative Erasmus + project, 'O-Health-Edu'. The project aims to better understand the existing state of oral health professional education in Europe and to develop a common vision of this education and support changes by 2030. These changes would allow the profession to be in a greater position to meet the oral health needs of the European population. The aim of this scoping review is to investigate how oral health professional education in Europe is reported.

2 | METHODS

The PRISMA Extension for Scoping Reviews and the Arksey & O'Malley methodological framework for scoping reviews were used to guide the reviewers throughout the scoping review process.[8,9]

These frameworks allow for the identification of both in-depth and broad literature. In a systematic review, the data collected is guided by a highly focussed research question and very specific study designs. In contrast, the approach used here aimed to identify all relevant literature, regardless of its construct or quality.

2.1 | Search strategy

The search strategy (Figure 1) was developed from the research question "How is oral health professional education reported in Europe?". The search strategy encompassed published literature searches, internet searches and further searching of relevant documents from educational organisations, regulators and professional bodies. The specific search terms for each search undertaken can be seen in Table 1. In order to identify relevant published studies, both educational (Education Resources Information Center—ERIC) and scientific databases (PubMed) were used. As well as searching for published sources, a Google Scholar and two separate Google web searches were carried out. For the latter, the first 100 sources were considered. Finally, websites of known Educational Organisations, Regulators, Data Reporting Agencies, Professional Bodies and Health Agencies were hand-searched for further relevant sources. After screening the results of the published literature search, handsearching of the references of included sources was undertaken to identify further sources.

The authors felt a systematic and wide-ranging search strategy across the data sources would give a more comprehensive picture of the reporting of oral health professional education in Europe. Therefore, no limitations were placed on year of publication although only articles in English were accepted. Once the search strategy was developed, it was sent to key stakeholders for consultation; the list of these can be seen in Table 2. After considering feedback from all stakeholders, the search strategy was finalised. The searches were undertaken in a period from the beginning of December 2019 to the end of February 2020.

2.2 | Selection of sources of evidence (Screening)

The title and abstracts of all sources identified from the searches were retrieved and screened by two authors (JD, JF). Sources were included in the scoping review if they reported on oral health professional education in Europe, regardless of the level of reporting, study type or subject matter. The EHEA definition of Europe was used to determine the inclusion of relevant articles. If the source did not have an abstract or if the data reported were unclear from the abstract, the full-text document was retrieved and screened by both authors concurrently. Equally, if a unanimous agreement could not be established from the abstract, the full-text document was retrieved to determine its inclusion in the scoping review. If there was disagreement when screening, the issue was discussed further with the other authors in order to reach a consensus.

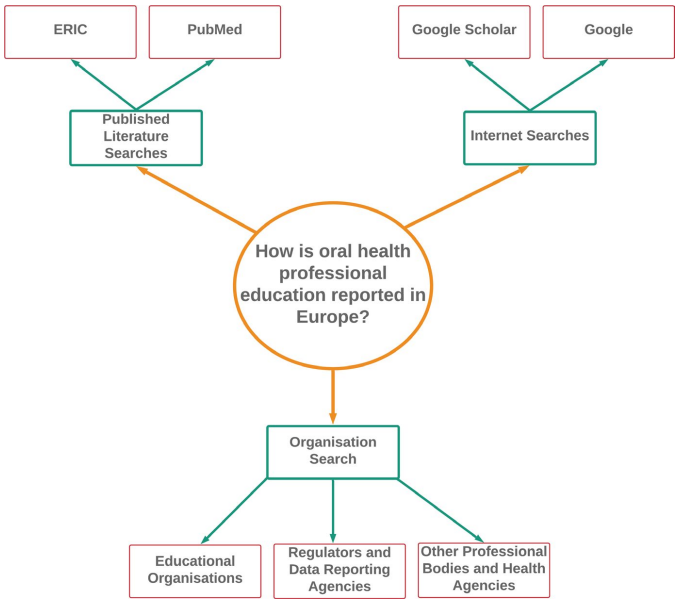

FIGURE 1 Search Strategy

TABLE 1 Individual search terms for each search undertaken

Search	Search terms
ERIC and PubMed	[All] Dental OR Oral Health OR Dental Student OR Dental graduate OR Hygienist OR Hygiene OR dental therapy OR dental therapist AND Education [Title/Abs] Europe AND Report No date restrictions, English only
Secondary PubMed	[All] Dental OR Oral Health Professional OR Dental Student OR Dental graduate OR Hygienist OR Hygiene OR dental therapy OR dental therapist AND Education [Title/Abs] Europe AND Survey No date restrictions, English only
Google Scholar	Dental OR Oral Health AND Education AND Delivery OR Europe
Google Search 1	"Europe Dental Education Delivery Report"
Google Search 2	"Europe Oral Health Education Delivery Report"
Educational Organisations	Handsearching websites of ADEE, ADEA, CECDO, EDSA, EDHF, IADR, IFDEA, FEHDD, Dental School Councils, identifiable through web searches
Regulators and Data Reporting Agencies	Handsearching websites of FEDCAR, EUROSTAT, Eurydice, ENQA, country-specific regulators, identifiable through web searches
Other Professional Bodies and Health Agencies	Handsearching websites of CED, FDI, country-specific bodies, identifiable through web searches

TABLE 2 Key stakeholders approached to help shape the search strategy

British Dental Association
Council of European Chief Dental Officers
Council of European Dentists
European Dental Hygienists Federation
European Dental Students' Association
FDI—Fédération Dentaire Internationale
FEDCAR—Federation of European Dental Competent Authorities and Regulators
Irish Dental Council

2.3 | Data charting process

All final sources included in the scoping review were read in full text and subsequently recorded in the charting form—an example of which can be seen in Figure 2. The data recorded included the following: author(s), year of publication, title, journal or publisher name, study type, location, and the subject matter reported. This form allowed for the appropriate organisation of included sources and for a standardised extraction of data relevant to the scoping review. The decision on which variables were used to extract data from each source was based on the research question. It was not within the scope of the review to report the full research findings of each study; instead, any data relating to *how oral health professional education was provided or delivered in Europe* was recorded in the charting form.

Similar to the screening process, the two lead authors (JD,JF) reviewed all of the included studies and charted them as per the information previously. Due to the novel nature of the subject of the scoping review, it was not possible to plan calibration of reviewers prior to charting; however, as this process continued, both reviewers were in communication to standardise the procedure.

2.4 | Data analysis

In line with the recommendations by Arksey and O'Malley,[9] the search terms were slightly refined as the lead authors became more familiar with the reviewed literature. This allowed a second and more sensitive search of the literature. As such, a second PubMed search was undertaken to exclude the term "report" and to include the term "survey." This change in search terms was undertaken due to the common use of survey methodologies in included studies.

Once data from all included sources were charted, the data were analysed by the lead authors (JD, JF). Year of publication, journal/publisher, study type and location reported were analysed quantitatively with means, modes and percentages calculated to demonstrate the average and most common findings. Due to the predominantly qualitative nature of the data, the "subject matter reported" data were analysed using the six-phase

Author	Year	Title	Journal/Publisher	Study/ Source type	Location Reported	Subject Matter Reported
Luciak-Donsberger & Eaton	2009	Dental hygienists in Europe: trends towards harmonization of education and practice since 2003	International Journal of Dental Hygiene	Survey and Interview	Europe	23 EU countries surveyed on offering DH education, duration of study, diploma type, dual education DH & DT, harmonisation in Europe? Prerequisites, institutional settings, patterns of change in programmes, ECTS, total hours, PG eduction for DH&T, regulation trends in EU, practice supervision/direct access per country.
Gürsoy *et al.*	2018	Periodontal education and assessment in the undergraduate dental curriculum-A questionnaire-based survey in European countries	European Journal of Dental Education	Survey	Europe (EFP member institutitions)	Survey of European Federation of Periodontology (EFP) members. Reports on periodontal education and assessment in Europe: mimimum competences, pedagogical delivery methods, time allocated, assessment methods, student access to complex periodontal management techniques.
Council of European Chief Dental Officers (CECDO)	2017	CECDO EU & EEA Database	Council of European Chief Dental Officers (CECDO)	Database	Europe	Database on population, workforce and education. Reports on number of schools, public/private, entries, % of females, graduates, total intake as a country, course duration, school closures, VT, Hygienist courses, duration and diploma type, possibility of further therapist training.

FIGURE 2 Example of an entry into the data charting form

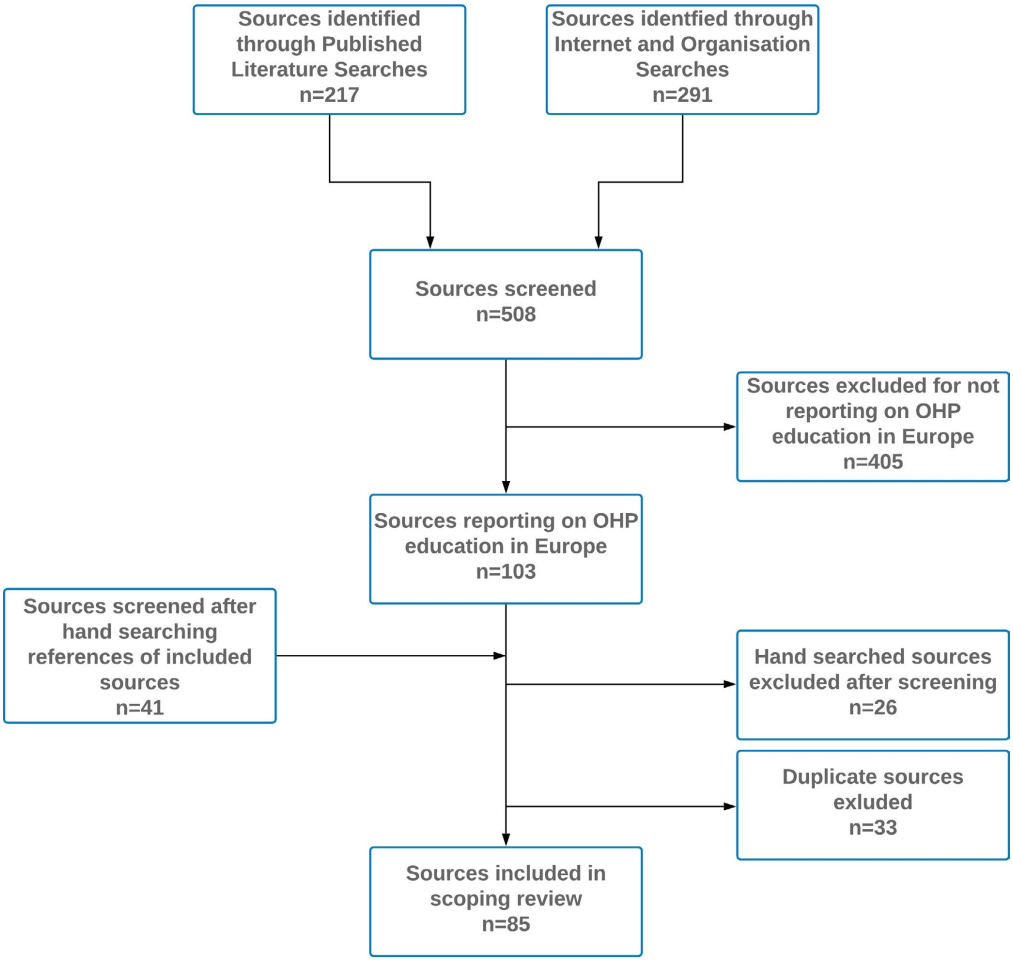

FIGURE 3 Results flow chart

guide to thematic analysis outlined by Braun and Clarke.[10] This process involved familiarisation with the data, coding and subsequent naming and data separation into themes. Themes were highlighted according to relevance or "keyness" to the research question rather than a purely focussing on their prevalence in the results.[10]

TABLE 3 Sources included in the scoping review and a summary of the data extracted

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Addy et al[11]	The teaching of implant dentistry in undergraduate dental schools in the United Kingdom and Ireland	2008	Published Literature	Survey	Implantology curricula and teaching	UK and Ireland	Discipline level
Afsharzand et al[12]	Predoctoral implant dentistry curriculum survey: European dental schools	2005	Published Literature	Survey	Implantology curricula	Europe	Discipline level
Alsafi et al[13]	Achieved competencies in TMD	2015	Published Literature	Survey	TMD (temporomandibular disorder) competencies	Europe	Discipline level
Atashrazm et al[14]	Worldwide Predoctoral Dental Implant Curriculum Survey	2011	Published Literature	Survey	Implantology curricula	Global	Discipline level
Atkin[15]	Human disease/clinical medical sciences for dentistry in early-years dental graduates: Transition from undergraduate study to clinical practice	2019	Published Literature	Survey	Graduate experience of undergraduate teaching of human diseases	Wales	Discipline level
Bánóczy[16]	The evolution of dental education—a European perspective	1993	Published Literature	Opinion	Evolution of dental education	Europe	Programme level
Bánóczy and Ray[17]	Process and outcome of a visitation to a Central European dental school	1998	Published Literature	Visitation report	Programme review	Semmelweis University, Hungary.	Programme level
Bánóczy[18]	Harmonisation of dental education and curricula in Europe	1999	Published Literature	Narrative report	History of dental education	Europe	Programme level
Beeley[19]	Nutrition in dental education: a European perspective	1997	Published Literature	Survey	Nutrition curricula	Europe	Discipline level
Brand et al[20]	A survey of local anaesthesia education in European dental schools	2008	Published Literature	Survey	Local anaesthetic curricula	Europe	Discipline level
Buerkle et al[21]	Restoration materials for primary molars-results from a European survey	2005	Published Literature	Survey	Restorative materials used for primary teeth	Europe	Discipline level
Bullock et al[22]	Continuing professional development systems and requirements for graduate dentists in the EU: survey results from the DentCPD project	2013	Published Literature	Survey	CPD systems and requirements	Europe	Postgraduate education and CPD
De Boever[23]	Undergraduate and graduate education in prosthodontics in continental Europe	1989	Published Literature	Survey	Prosthodontic teaching and training time in undergraduate and postgraduate programmes.	Select European countries	Discipline level, Postgraduate education and CPD
De Bruyn et al[24]	A survey on undergraduate implant dentistry education in Europe	2009	Published Literature	Survey	Implantology curricula	Europe	Discipline level

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Durocher[25]	Potential models in Europe for dentistry in the United States—a report	1969	Published Literature	Narrative report	Degree titles, length of training, curriculum content, clinical targets, course hours, naming of specialties.	Europe	Programme level
Field et al[26]	Curriculum content and assessment of pre-clinical dental skills: A survey of undergraduate dental education in Europe	2018	Published Literature	Survey	Preclinical skills curricula	Europe (ADEE member institutions)	Discipline level
Gaengler et al[27]	Special report: ADEE INITIATIVE. The positive tendency in approaches to the dental curriculum in Belarus: a report arising from a WHO-sponsored visitation to schools in the former USSR and Eastern Europe and a follow-up invited visit of ADEE/AADS representatives to Minsk, Belarus	2002	Published Literature	Visitation report	Programme review	Minsk, Belarus	Programme level
Gatermann-Strobel and Perno Goldie[28]	Independent dental hygiene practice worldwide: a report of two meetings	2005	Published Literature	Narrative report	Duration & cost of dental hygiene education	Europe, The United States and Canada	Other Oral Health Professional Education
Gürsoy et al[29]	Periodontal education and assessment in the undergraduate dental curriculum-A questionnaire-based survey in European countries	2018	Published Literature	Survey	Periodontology curricula and competences	Europe (EFP member institutions	Discipline level
Harzer et al[30]	Undergraduate orthodontic & paediatric dentistry education in Europe—the DentEd project	2001	Published Literature	Guidelines	Orthodontic and paediatric curricula	Europe	Discipline level
Harzer et al[31]	Harmonisation of Dental Education in Europe—a survey about 15 years after visitation of dental schools participating in the DentEd project	2017	Published Literature	Survey	Curricula, Facilities, ECTS allocations	Europe	Programme level
Hey et al[32]	Content and goals of preclinical prosthodontic programs at German-language dental schools	2014	Published Literature	Survey	Preclinical prosthodontic curricula and learning outcomes	German-speaking schools	Discipline level
Huggare et al[33]	The Erasmus programme for postgraduate education in orthodontics in Europe: an update of the guidelines	2014	Published Literature	Guidelines	Postgraduate orthodontic training in Europe	Europe	Postgraduate education and CPD
Jaber et al[34]	Spanish dental students knowledge of oral malignancy and premalignancy	1997	Published Literature	Survey	Undergraduate experience with oral malignancies	Spain	Discipline level

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Johnson[35]	International profiles of dental hygiene 1987 to 1998: a 19-nation comparative study	2001	Published Literature	Survey and narrative report	Number of programmes per country, length, number of graduates, professional regulation, scope of practice	International Federation of Dental Hygienist members	Other Oral Health Professional Education
Koole et al[36]	Implant dentistry education in Europe: 5 years after the Association for Dental Education in Europe consensus report	2014	Published Literature	Survey	Undergraduate & postgraduate implant training, preclinical vs clinical implant education	Europe	Discipline level, Postgraduate education and CPD
Koole and De Bruyn[37]	Contemporary undergraduate implant dentistry education: a systematic review	2014	Published Literature	Narrative report	Implant curricula and clinical training	Global	Discipline level
Kroeplin and Strub[38]	Implant dentistry curriculum in undergraduate education: part 1-a literature review	2011	Published Literature	Literature review	Implant curricula and student experience	The United States and Europe	Discipline level
Luciak-Donsberger[39]	The effects of gender disparities on dental hygiene education and practice in Europe	2003	Published Literature	Narrative report	Gender disparity of dental hygienists Dental hygiene courses per country, programme details	Europe	Other Oral Health Professional Education
Manogue et al[40]	Curriculum structure, content, learning and assessment in European undergraduate dental education—update 2010	2011	Published Literature	Guidelines	Length of programmes in EU, vocational training, curriculum structure	Europe	Programme level
McDonald et al[41]	A survey of postgraduate (specialist) orthodontic education in 23 European countries.	2000	Published Literature	Survey	Orthodontics specialty training settings, funding, assessment.	Europe	Postgraduate education and CPD
Monteiro et al[42]	The teaching of management of the pulp in primary molars across Europe.	2017	Published Literature	Survey	Pulp management in primary molars: techniques and materials.	Europe	Discipline level
Nasseripour et al[43]	Oral surgery in the European Union: challenges of diversity in training and practice	2017	Published Literature	Survey	Postgraduate oral surgery training in Europe including scope of practice	Europe	Postgraduate education and CPD

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Nilner et al[44]	Guidelines for curriculum of undergraduate and postgraduate education in orofacial pain and temporomandibular disorders in Europe.	2003	Published Literature	Guidelines	Curriculum guidelines for orofacial pain and TMD	Europe	Discipline level, Postgraduate education and CPD
Paravina et al[45]	Teaching of color in predoctoral and postdoctoral dental education in 2009	2010	Published Literature	Survey	Teaching of colour in dentistry	Global	Discipline level
Perry et al[46]	Simulation and curriculum design: a global survey in dental education	2017	Published Literature	Survey	Curricula trends in dental education	Global	Programme level
Petersson et al[47]	Undergraduate education in endodontology at two European dental schools	2002	Published Literature	Survey	Undergraduate endodontic training: educational methods, clinical procedures and assessment	Malmo, Sweden Paris, France	Discipline level
Rüttermann et al[48]	Teaching and assessment of communication skills in undergraduate dental education - a survey in German-speaking countries	2017	Published Literature	Survey	Communication skills training, timing, assessment.	German-speaking European countries	Discipline level
Scott[49]	Convergence in dental education: The DENTED project	1999	Published Literature	Narrative report	Disparities in clinical training	Europe	Programme level
Scott[50]	Dental education in Europe: the challenges of variety	2003	Published Literature	Narrative report	Differences in degree titles & training, number of schools, graduates, dentists, curricular differences.	Europe	Programme level
Serrano et al[51]	Challenges in the transition to clinical training in dentistry: An ADEE special interest group initial report	2018	Published Literature	Survey and working group consultation	Programme duration, entry requirements, curriculum design, preclinical course design & clinical training.	ADEE member institutions	Programme level Discipline level
Shanley et al[52]	Undergraduate training in the European Union Convergence or divergence?	1997	Published Literature	Survey	Curriculum design, Quality Assurance processes, student selection	Europe	Programme level
Sieminska-Piekarczyk et al[53]	A survey of perceived problems in orthodontic education in 23 European countries	2000	Published Literature	Survey	Perceived problems with orthodontic postgraduate training.	Europe	Postgraduate education and CPD
Ucer et al[54]	Current trends and status of continuing professional development in implant dentistry in Europe	2014	Published Literature	Survey	Trends and status of CPD in implant dentistry in Europe.	Europe	Postgraduate education and CPD

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
van der Linden et al[55]	European orthodontic specialists in 2002	2004	Published Literature	Survey	Orthodontic specialists in Europe, training and availability.	Europe	Postgraduate education and CPD
Vasak et al[56]	Current state of training for implant dentistry in Europe: a questionnaire-based survey	2007	Published Literature	Survey	Continuing education courses in implant dentistry, course length, delivery, types of attendees.	Europe	Postgraduate education and CPD
Wilson & Alcaino[57]	Survey on sedation in paediatric dentistry: a global perspective	2011	Published Literature	Survey	Behaviour management techniques used in postgraduate paediatric dental training.	Global	Postgraduate education and CPD
Wilson & Mjör[58]	The teaching of Class I and Class II direct composite restorations in European dental schools	2000	Published Literature	Survey	Teaching of posterior composite restorations	Europe	Discipline level
Wilson & Setcos[59]	The teaching of posterior composites: a worldwide survey	1989	Published Literature	Survey	Teaching of posterior composites	Global	Discipline level
Wilson et al[60]	Preclinical Operative Dentistry Courses in Northern Europe and Scandinavia	1993	Published Literature	Survey	Preclinical operative skills course curricula variation	Northern Europe and Scandinavia	Discipline level
Zelles et al[61]	Basic science teaching in dentistry in Central/Eastern Europe. Towards harmonisation?	2011	Published Literature	Survey	Time devoted to basic sciences.	Central and Eastern Europe	Discipline level
Luciak-Donsberger & Eaton[62]	Dental hygienists in Europe: trends towards harmonization of education and practice since 2003	2009	Internet	Survey and interview	Dental hygiene curricula, entry requirements and regulation	Europe	Other Oral Health Professional Education
Schulte *et al* [63]	A survey on education in cariology for undergraduate dental students in Europe	2011	Internet	Survey	Undergraduate cariology curricula	Europe	Discipline level
Luciak-Donsberger[64]	Origins and benefits of dental hygiene practice in Europe	2003	Internet	Survey and narrative report	History of dental hygiene, programme details, regulation and scope of practice	Europe	Other Oral Health Professional Education
Barnes et al[65]	A review of continuing professional development for dentists in Europe	2013	Internet	Literature review	CPD in Europe: dentist engagement in CPD, common modes of delivery and their effectiveness	Europe	Postgraduate education and CPD

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Mattheos et al[66]	Developing implant dentistry education in Europe: the continuum from undergraduate to postgraduate education and continuing professional development	2014	Internet	Consensus workshop report	Implant curricula, recommendations	Europe	Discipline level, Postgraduate education and CPD
Preshaw & Mohammad[67]	Geriatric dentistry education in European dental schools	2005	Internet	Survey	Geriatric dentistry curricula	Europe	Discipline level
Sanz et al[68]	Is there a need for a common framework of dental specialties in Europe?	2008	Internet	Narrative report	Specialties and training across Europe	Europe	Postgraduate education and CPD
Martínez-Álvarez et al[69]	Basic sciences education in the dental curriculum in Southern Europe	2001	Internet	Survey	Science curricula and staffing	Southern Europe	Discipline level
Seckinger et al[70]	The status of undergraduate implant education in dental schools outside the United States.	1995	Internet	Survey	Undergraduate implant training	External to United States	Discipline level
Keevil[71]	Faculty openings and recruitment in dental hygiene education	1992	Internet	Survey	Recruitment and staffing of hygiene programmes	Global	Other Oral Health Professional Education
Dummer[72]	Comparison of undergraduate endodontic teaching programmes in the United Kingdom and in some dental schools in Europe and the United States	1991	Internet	Survey and visitation report	Endodontic undergraduate curriculum	Europe and United States	Discipline level
Health Education England[73]	Advancing Dental Care: Education and Training Review. Final report	2018	Internet	Report	Oral health professional (OHP) workforce number in UK, scope of practice of OHP, applications to dental and DH&T courses, dental foundation training, postgraduate training, speciality training, dental school income	UK	Programme level, Other Oral Health Professional Education, Postgraduate education and CPD
Chuenjitwongsa[74]	Developing Educators of European Undergraduate Dental Students: Towards an Agreed Curriculum	2015	Internet	Literature review	Bologna process harmonisation towards odontology programmes, directive 78/687/EEC describing list of subjects required for a dental programme	Europe	Programme level

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Tsuruta[75]	Comparison of the quality assurance system of dental professionals in Japan, the EU and the ASEAN	2019	Internet	Narrative report	QA systems	Europe, Japan and South-East Asia	Programme level
Jayachandran et al[76]	Maintaining dental implants—do general dental practitioners have the necessary knowledge?	2015	Internet	Survey	Implant knowledge and training of primary care dentists	West Midlands, UK	Postgraduate education and CPD
Wikipedia[77]	"Dentistry"		Internet	Website	Reports that dental education in EU must be at least 5 years, vocational training.	n/a	Programme level
University of Glasgow[78]	Self-Evaluation Report	2010	Internet	Educational review	Programmes review	Glasgow, Scotland	Programme level
NHS Scotland[79]	Dental Workforce Report December 2014	2014	Internet	Workforce report	Applicants to dental school, intake targets, total number of students entering BDS/BSc/DH&T programmes, demographics of students starting BDS course, completion rates, bursaries, vocational training.	Scotland	Programme level, Other Oral Health Professional Education, Postgraduate education and CPD
European Commission[80]	EAHC/2013/Health/07 Study concerning the review and mapping of continuous professional development and lifelong learning for health professionals in the EU	2013	Internet	Narrative report	CPD across EU all health professionals. Country-by-country guide on dentists mandatory & voluntary CPD, organisational providers, law, monitoring, enforcement, accreditation, financing	Europe	Postgraduate education and CPD
Robb[81]	Pain and anxiety control in dentistry—the foundation of successful practice, but the cinderella of dental pre-registration education	2017	Internet	Narrative report	Anxiety and pain management curricula	UK	Discipline level

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Postgraduate Medical Education and Training Board[82]	PMETB report on training in Oral and Maxillofacial Surgery (OMFS)	2008	Internet	Narrative report	OMFS specialty training	UK	Postgraduate education and CPD
Nash et al[83]	A review of the global literature on dental therapists	2014	Internet	Literature review	Dates of adoption of dental therapy by country, length of training of therapists, scope of practice.	Global	Other Oral Health Professional Education
National Health Service[84]	Dentists Act	1984	Internet	Legal document	Reports on General Dental Council, education, supervision.	n/a	Programme level
Health Education England[85]	The Future Oral and Dental Workforce for England. Liberating human resources to serve the population across the life-course	2019	Internet	Workforce report	Number of dental schools in UK, number of students vs number of applicants, DH&T education settings, hygienist education vs DH&T education, technology programmes in UK, orthodontic therapy programmes, dental nurse programmes, gender of workforce.	UK	Programme level, Other Oral Health Professional Education, Postgraduate education and CPD

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
European Union[86]	Mutual evaluation of regulated professions. Overview of the regulatory framework in the health services sector—dental hygienists and related professions	2016	Internet	Narrative report	Report on the education of OHPs. Number of dental hygiene schools, students per year, number of hygienists working as educators, regulation of OHPs, activity/scope of practice for each country, autonomy of DH&T, degree titles, length of training, registration with professional bodies, CPD, regulation, link to dentists, periodontists, technicians and dental nurses.	Europe	Other Oral Health Professional Education
Lynch et al[87]	Community-based dental hygiene and therapy education	2011	Internet	Survey and narrative report	Dental hygiene and therapy student's thoughts on the community-based teaching.	UK	Other Oral Health Professional Education
UK Parliament[88]	Health Committee—Written evidence from the General Dental Council (ETWP 111)	2012	Internet	Legal document	GDC learning outcomes, CPD, scope of practice.	n/a	Programme level, Postgraduate education and CPD
ADEE[89]	Monitoring & assessment in undergraduate Endodontology; towards a European standard	2015	Organisation	Website – ADEE special interest group outputs	Undergraduate endodontology curricula	Europe	Discipline level

(Continues)

TABLE 3 (Continued)

Author	Title	Year	Search	Type	Subject matter reported	Location reported	Reporting theme
Council of European Chief Dental Officers (CECDO)[90]	CECDO EU & EEA Database	2017	Organisation	Database	Database on population, workforce and education. Reports on number of schools, public/private, entries, % of females, graduates, total intake as a country, course duration, school closures, vocational training, hygienist courses, duration and diploma type, possibility of further therapist training.	Europe	Programme level, Other Oral Health Professional Education
Council of European Dentists (CED)[91]	Manual of Dental Practice (Edition 5.1)	2015	Organisation	Report	EU directives, basic dental training requirements, country-specific capacity for dental training, number of schools, vocational training requirements	Europe	Programme level
Council of European Dentists (CED)[92]	CED-ADEE Joint Statements on Basic Dental Training	2013	Organisation	Statement	Time and credit recommendations	n/a	Programme level
Council of European Dentists (CED)[93]	Revised CED Resolution—Annex V.3/5.3.1 of Directive 2005/36/EC	2016	Organisation	Guidelines	Proposed changes to annex of subjects taught due to outdated terminology and the frequency of other subjects being present in curricula.	n/a	Programme level
Council of European Dentists (CED)[94]	CED Statement—Specialist Dentists	2016	Organisation	Statement	Recognition of dental specialties	n/a	Postgraduate education and CPD
European Dental Students' Association (EDSA)[95]	Clinical Practice in EU Dental Schools: Preliminary Results	2016	Organisation	Survey	Clinical procedures performed & amount, confidence in autonomous practice.	Europe	Programme level

3 | RESULTS

3.1 | Selection of sources of evidence

A flow chart demonstrating the results of the searches undertaken, the number of sources screened and ultimately included in the scoping review can be seen in Figure 3. A total of 217 published articles were retrieved from the primary and secondary PubMed and ERIC searches. A total of 291 sources were identified through the Internet and organisation searches, leaving a total of 508 sources to be screened. A total of 405 sources were excluded as they did not report on the topic of interest, leaving 103 sources that reported on oral health professional education in Europe. Handsearching of the references of the included and published sources leads to a further 41 articles being screened, in which 15 sources reported on oral health professional education in Europe. In total, 33 duplications were removed and the final number of included sources was 85.

3.2 | Characteristics of sources of evidence

The individual characteristics of all the included sources, as well as a summary of the data extracted (using the charting form Figure 2) from each source, are presented in Table 3. The table also describes the search in which the source was found, as well as the reporting theme.

A summary of the most common characteristics of the whole dataset can be seen in Table 4. The mean year of publication for all included sources was 2007. The majority of sources were published in a journal dedicated to dental education (48%), with discipline-specific journals also being relatively common (29%). Surveys represented the most common source type (55%), with narrative reports, guidelines and literature reviews also being frequent (26% combined). 57% of sources reported across Europe, a combined 25% for either individual countries or select regions within Europe and 18% globally.

Thematic analysis of the subject matter reported by all included sources revealed four broad reporting themes:

- Dental education at a programme level
- Dental education at a discipline level
- Other oral health professional education
- Postgraduate education and continuous professional development (CPD)

The four themes and the most common information reported by all included sources can be seen in Table 5.

3.3 | Dental education at a programme level

The web search of dental organisations and professional bodies revealed two important documents that present data on dental education from countries in the EU and EEA.[90,91] These documents contain a large amount of data from dental schools across Europe—something many of the other programme-level reports fail to provide. As these documents are written by political organisations, there is a heavy focus on the dental and oral health workforce—and therefore most of the educational data presented focuses on length of study, number of dental schools, graduate numbers, clinical experience and vocational training. Whilst these are all essential factors in dental education and ultimately managing the oral health needs of the public, there is an evident lack of data on educational strategies and principles.

3.4 | Dental education at a discipline level

More than half of the relevant studies from the published literature searches report on dental education at a discipline level.[11-15,19-21,23,24,26,29,30,32,34,36-38,42,44,45,47,48,51,58-61] Implantology[11,12,14,24,36-38,66,70] was the most commonly reported discipline, with Paediatric Dentistry,[21,30,42] Endodontology[47,72,89] and Operative Dentistry[58-60] also being reported frequently. Resources that reported on dental education at a discipline-level tended to be much more focused on educational practice, rather than political drivers. Discipline and sub-course curricula, teaching methods, sub-course duration, educational settings, clinical experience and assessment were commonly reported, as seen in Table 5.

3.5 | Other oral health professional education

The majority of the data reported for oral health professional education focused on dental hygienist education,[28,35,39,62,64,71,86] with some reporting on both dental hygiene and therapy (DH&T) education.[73,79,85,87,90] None of the reports found in the searches reported on

TABLE 4 Most common characteristics of whole dataset

Data Variable	Findings
Mean Year of Publication	2007
Year of Publication Range	1969-2019
Most Common Journal Type	Dental Education Journals 48% Dental Discipline-specific Journals 29% Dental Scientific Journals 14% Country-specific Journals 9%
Most Common (Modal) Source Type	Survey
Most Common Location Reported	Europe 57% Global 18% Individual Countries 15% Select European Countries 10%
Subject Matter Themes	1. Dental education at a Programme Level 2. Dental education at a Discipline Level 3. Other Oral Health Professional Education 4. Postgraduate Education and Continuous Professional Development (CPD)

dental nurse or dental technology education, and this may be due to the fact that these programmes are still often delivered as vocational or further education programmes, outside of the usual higher education setting. Such a trend may also be expected considering that many countries are increasingly focusing on training dental hygienists and therapists to meet the oral health needs of their population. Nonetheless, the data available regarding dental hygiene education provide a significantly more comprehensive programme review across multiple countries and institutions in Europe, than the data for dentistry.

Considering the large variety of regulations for dental hygienists,[2] there have been a number of reports that have attempted to provide details on these variances.[28,35,62,64,83] These reports cover most countries in Europe and include very useful data on length of study, scope of practice, regulation, educational attainment and historical aspects of dental hygiene, such as year of implementation. One study, by Luciak-Donsberger and Eaton,[62] which used surveys and interviews across Europe, focuses more on the educational strategies of dental hygiene programmes in Europe. The article reports on the number and duration of study of dental hygiene programmes in European countries, as well as the educational attainment but then details educational trends in Europe, with a focus on settings and supervision.

3.6 | Postgraduate education and continuous professional development (CPD)

Postgraduate education, similar to the discipline-level data, reported more frequently on educational aspects such as curricula and training settings. Of the included studies that reported on postgraduate education, most described the current state at a discipline level.[33,36,43] This trend of reporting of speciality training at a discipline level is to be expected, as many of the specialties work independently to develop their programmes. However, Sanz et al published a report on the accepted specialties per country in Europe, as well as training regulation and the numbers of specialty dentists in Europe.[68]

The regulation of CPD, country-specific requirements and modes of delivery were commonly reported in included studies. The DentCPD project and the Graduating European Dentist highlight the importance of lifelong learning through engagement with continuing professional development (CPD).[7,96] Barnes et al carried out a literature review of CPD in Europe and reported on dentist engagement in CPD, common modes of delivery and their effectiveness.[65] Much of the data in this literature review was from a select list of countries, mainly those that have regulated CPD activity. An EU-funded study that reviewed CPD and lifelong learning of health professionals in the EU was found in the Internet search.[80] This mapped the mandatory and voluntary CPD requirements according to each country in the EU, as well as reporting on common topics specific to dentistry and their mode of delivery.

4 | DISCUSSION

This scoping review has highlighted that the reporting of oral health professional education in Europe is limited. The literature search revealed some useful documents that report a wide breadth of data on oral health professional education; however, these tended to either

TABLE 5 Subject matter themes and common information reported for each

Subject matter theme	Common information reported
Dental Education at a Programme Level	Length of study[25,40,51,77,90]
	Historical structure and curricula[18,25,31,40,50,52,74]
	Clinical training/experience[25,49,51,95]
	Vocational training[40,73,77,79,90]
	Number of dental schools and graduates[73,79,85,90]
Dental Education at a Discipline Level	Sub-course curricula[11,12,14,19,20,24,26,29,30,32,37,38,44,51,60,63,66,67,69,72,89]
	Teaching methods[23,42,45,47,48,70]
	Educational setting and clinical experience [36-38,47,51,70]
	Competencies and Assessment[13,29,47,48,89]
	Sub-course duration[23,36,48]
Other Oral Health Professional Education	Length of study[28,35,39,64,83,86,90]
	Scope of practice[35,64,73,83,86]
	Regulation by country[35,62,64,86]
	Entry and graduate numbers[35,62,86]
	Educational attainment[86,90]
Postgraduate Education and Continuous Professional Development (CPD)	Postgraduate curricula[33,43,55,57,82]
	CPD regulation and requirements[22,65,80]
	Delivery of CPD[54,56,65,76]
	Specialty recognition[55,68,82,94]
	Postgraduate training settings[41,73]

cover a small number of institutions or report at a national level, rather than giving a broader picture in Europe. Considering that the average year of publication of relevant articles was 2007, much of this data would now be considered outdated.

4.1 | Programme-level and discipline-level data

There are a number of useful documents that provide advice and guidelines at a programme level,[7,40,97] as well as at an individual discipline level.[33,66,98] However, these do not report on the *current* state of oral health professional education in Europe and instead, list principles of good academic practice. In turn, we are unable to conclude to what extent this practice is adopted by institutions across Europe. The lack of reporting of dental education at a programme level is a concern. Comprehensive and geographically wide-ranging data on curriculum content and design, student assessment, admissions and clinical academic staff are more difficult to find. Articles that report on educational practices tend to have relatively small cohorts and many are outdated with current recommendations. Following the Bologna Agreement and the DENTEd project, which both aimed to drive harmonisation of dental education in Europe, many of the relevant articles from the published literature search reported on differences between historical dental education and aims for the future, with numerous papers describing the stomatology model vs odontology model. The focus on educational principles and practice by sources reporting discipline-level data is positive and allows for the sharing of best academic practice across institutions, as well as supporting decision-makers in planning changes to improve the quality of education delivered by their institution. The increase in publication of discipline and specialty-specific curricula is promising, and this is advocated within the Graduating European Dentist curriculum documents.[7]

4.2 | Postgraduate education and CPD

The reporting of postgraduate dental education, including specialty training, is similar to the reporting of dental education in general. According to the EU Directive 2005/36/EC, specialty training must be a minimum of three years full time, must have academic and clinical elements, and be delivered at approved institutions within the country concerned[1]—and whilst there are many useful guidelines on *how* postgraduate education and specialty training should be delivered, it is not clear from the published literature *what* is delivered. Although there are documents that report on the CPD requirements of some countries, more information is needed on the setting and method of delivery preferred by oral health professionals. Additionally, it is not known how well oral health professionals engage in CPD, which may subsequently lead to a change in their professional practice. It is evident that there is very little knowledge on the current state of postgraduate education and CPD *across* Europe and more wide-ranging and comprehensive reporting is required.

4.3 | Faculty-level data

Whilst programme-level and discipline-level data were most prevalent, there was an evident lack of data at a faculty level. This includes information about academic staff numbers, qualifications of academic staff, and the research and teaching experience of academic staff. One study reported on staff involved in the delivery of dental hygiene programmes, but this mostly covered the United States.[71] These data are of relevance to understand *how* education is delivered as well as how clinical academic staff balance their clinical, educational and research commitments—as such, there is a need for an increased reporting of this data, and for publications that provide advice and recommendations.

4.4 | Retrievability of sources

The authors were aware of other known sources that reported on dental education in Europe but were not found as part of this comprehensive search strategy (Table 6). The authors propose two potential reasons for known articles not appearing in the search: (a) variation in the use of keywords, and (b) the accessibility of the publishing website. The use of Medical Subject Headings (MeSH) keywords for publications is a useful tool to index and facilitate searching and access to articles. Recommended MeSH keywords related to dental education can be seen in Table 7. The fact that the majority of included sources were published in journals dedicated to dental education is positive—and allows for greater retrievability of sources. Many of the relevant articles that reported on dental education were linked to ADEE taskforces, workshops and Special Interest Groups. Whilst this serves to highlight the vital role that ADEE plays in mediating pan-European activities, it is important to ensure that this activity is written up and published in a timely fashion in order to ensure that the findings are recorded, accessible, and able to be referenced appropriately. It was positive to note that a

TABLE 6 Known documents that report on dental education but were not identified in searches

Articles known to the authors but not found in search:
ADEE. 2016. Survey of Dental Education in Europe Summary Report.[99]
General Dental Council. 2019. A Review of the Literature on Continuing Professional Development (CPD). Available fromhttps://www.gdc-uk.org/docs/default-source/research/181205-full-report-review-of-the-literature-on-cpd.pdf?sfvrsn=a4c63719_2[100]:
Martin, N., Fairclough, A., Smith, M. & Ellis, L. 2011. Clinical educators' views on the quality of undergraduate clinical restorative dentistry in the UK and ROI *Eur J Dent Educ*, 15, 216-222.[101]
Sinclair, E., Eaton, K. & Widström, E. 2019. The healthcare systems and provision of oral healthcare in European Union member states. Part 10: comparison of systems and with the United Kingdom. *Br Dent J*, 227, 305-310.[102]

number of sources identified through the online search results and hand searching, linked to a range of relevant dental educational organisations and professional bodies. However, finding these particular documents took a significant amount of time—and this finding may support the idea of a dynamic, easy-to-update central online toolkit that reports on dental education in Europe.

4.5 | Limitations of this scoping review

Potential limitations of the search strategy employed by the authors may include the inclusion of articles in English only. Whilst including articles in languages other than English may have led to more relevant articles, it is the opinion of the authors that including these would not significantly change the findings of the scoping review. With any search strategy, there is the potential for missed articles; however, the addition of the secondary PubMed search, once the authors were more familiar with the data set, strengthened the search strategy further.

4.6 | Recommendations for future reporting of dental and oral health professional education

- There is a greater need for comprehensive, educationally driven programme-level data on oral health professional education across Europe.
- Continued publication of discipline-level curricula, in line with the Graduating European Dentist recommendations.
- Increased reporting of faculty-level data, including staff numbers, clinical and research experience and educational qualifications.
- Increased reporting of postgraduate/specialty training and CPD, across all disciplines.
- Consistent use of MeSH keywords for publications in dental education (see Table 10 or use the MeSH browser https://meshb.nlm.nih.gov/search).
- Creation of a centralised online toolkit, in order to facilitate the collection, organisation, display and analysis of pan-European data relating to dental and oral health professional education.

TABLE 7 MeSH Keywords that can be used for publications in dental education

MeSH keywords for dental education
Dental education (Education, Dental)
Dental hygienists
Dentists
Dental students
Dental technicians
Dental assistants
Curriculum
Survey

5 | CONCLUSION

The reporting of dental and oral health professional education in Europe is limited. Whilst there are many useful documents that provide guidelines on dental education, there is limited knowledge on how education is implemented and delivered. There is a greater need for comprehensive educationally driven programme-level data on oral health professional education across Europe.

CONFLICT OF INTEREST

No conflict of interest has been declared by the authors.

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How to cite this article: Dixon J, Manzanares-Cespedes C, Davies J, et al. O-HEALTH-EDU: A scoping review on the reporting of oral health professional education in Europe. *Eur J Dent Educ*. 2020;00:1–22. https://doi.org/10.1111/eje.12577

A Vision for Oral Health Professional Education in Europe

Introduction

A core aim of the O-Health-Edu project was to develop a vision of OHP education for the future, which was collaboratively developed by multiple key stakeholders across the European continent. The vision will project how OHP education should be structured and delivered by 2040 and must align with the oral health needs of the population, as outlined in recent World Health Organisation strategies [316,317].

Methodology

The project team, which had extensive experience in curriculum development, developed a first draft of the vision elements. They reviewed and included the evidence base and stakeholder guidance documents regarding recent curriculum trends. The team then reviewed the vision elements iteratively. Once the group was satisfied with the terminology and content, an extensive pan-European consultation was planned that included all ADEE member institutions, international, national, and regional associations, regulators, industrial partners, and student representatives.

Results

A total of 96 responses were received for the consultation process, which included 13 different stakeholder groups. All responses were reviewed, and multiple amendments were made to the vision elements to improve the clarity of language and relevance of content. Seven vision elements were finalised and incorporated into a visual diagram. The elements centred around inclusive entry criteria for students, an integrated curriculum, an evidence-based education ensuring clinical and professional capability, a quality-assured curriculum, curricula that embed social responsibility, a collaborative curriculum that draws on best practices from the academic community and a curriculum that is responsive to local population needs.

Relevance

This project brought together an extensive group of stakeholders to establish a vision for OHP education in the future. This document provides OHP schools with an evidence-based, consensus-agreed vision for future curriculum development. The vision will also support the data collection stage of the O-Health-Edu project by providing a gold standard for comparing with existing practices. The vision serves as an additional driver for curriculum development and specifically environmental sustainability through demonstration of European-wide stakeholder agreement on the topic. The accepted approaches will inform future guidelines and recommendations in dental education and curriculum development.

Received: 8 January 2022 | Revised: 3 May 2022 | Accepted: 9 May 2022

DOI: 10.1111/eje.12819

COMMENTARY

WILEY

O-Health-Edu: A vision for oral health professional education in Europe

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Funding information
Erasmus+ A2 cooperation for innovation and the exchange of good practices / KA203 Strategic partnerships for higher education (2019-2022)

Abstract

This consensus paper reports on the process of developing a renewed vision for Oral Health Professional (OHP) education across Europe, and forms part of a larger EU-funded collaborative Erasmus+ project, "O-Health-Edu." The vision aligns with the World Health Organisation milestones (2016) and resolutions (2021), and EU4Health programme (2020) objectives - and projects 20 years into the future, to 2040. This longitudinal vision takes a multi-stakeholder perspective to deliver OHP education that acts in the best interests of both students and patients, and sits within the context of a wider strategy for general health. Included, it is an infographic to help communicate the vision to various stakeholders of OHP education.

KEYWORDS
consensus, education, Europe, oral health, students, World Health Organisation

1 | BACKGROUND

This position paper represents an outcome from a larger EU-funded collaborative Erasmus+ project, "O-Health-Edu." The project aims to better understand the existing state of Oral Health Professionals' (OHP) education in Europe and to develop a common vision for this education. The ultimate aim is to improve the ability of OHPs to meet the oral health needs of the European population. It is understood that promoting oral health will result in improved overall health, and a reduction in health inequalities—and indeed this objective is supported by the recent introduction of the EU4Health programme,[1] which, in part, aims to "strengthen health systems and the healthcare workforce". A major determining factor in this regard, is access to relevant, comprehensive and equitable people-centred

*World Health Organisation definition: "53 countries, covering a vast geographical region from the Atlantic to the Pacific oceans"

health services. The way in which relevant health professionals are educated, trained, and deployed, will determine each country's (and in turn, Europe's) capacity and capability to meet population health needs.

The term Oral Health Professional includes Dentists, Dental Therapists, Dental Hygienists, Dental Technicians and Dental Nurses (assistants). Considering the extensive remit of OHP education, and the lack of previous reviews of OHP education, the initial part of the project involved a scoping review.[2] The review focussed on the *reporting* of OHP education in Europe. The main finding was that there is limited published knowledge on educational practise and organisation across Europe.

The scoping review further identified four principal reporting themes, which helped the authors to summarise the current state of how OHP education was reported within Europe - these were:

- Dental (educating dentists) programme-level data
- Dental discipline-level data
- Other OHP data, and
- Postgraduate dental education and continuing professional development (CPD).

The findings are considered in more detail below:

1.1 | Programme and discipline-level data (dental)

Dental educators have a number of useful published guidelines at their disposal, that provide recommendations for how OHP education should be delivered at both a programme level (e.g.[3–5]), and discipline-level (e.g.[6–11]). As would be expected, the programme-level data offers local insights into the developing OHP workforce - such as student demographics, admissions and study length—however, these data provided little insight at a *European* level. The discipline-level data highlighted educational practices - such as sub-course duration, timing of courses within programmes, teaching methods, educational settings/resources, and assessment. Despite these snapshot examples of programme and discipline-level data, it is unclear exactly how OHP education is *currently* being delivered across the breadth of Europe. As such, the scoping review identified the need to collect contemporaneous pan-European data about current OHP education practice.

1.2 | Other OHP and postgraduate data

The scoping review found that most sources reporting on other OHP education (other than dentists), focused on dental hygienist education. There were no readily identifiable/searchable documents that reported on dental nursing, therapy or technology education. Of the data reported for dental hygienist education, common data themes presented were: length of study, scope of practice, regulation, educational attainment and historical aspects of dental hygiene education. Similarly, postgraduate education, specialty training and CPD, had a similar lack of reporting on educational practices. Sources regarding delivery of CPD generally originated from nations with regulated CPD activity.[12] Again, it is, unclear how other OHPs engage with CPD across Europe - and this has implications for workforce training and development.

1.3 | Publication patterns

The scoping review identified some publication patterns that may be restricting the accessibility of published information. Firstly, many of the included sources were published in journals dedicated to dental education only. Secondly, there were a number of publications known to the author team that were not found in the searches undertaken. The authors postulated that this may be due to a lack of appropriate Medical Subject Headings (MeSH) keyword attribution, or the sources were not all published in journals - instead, some being available through organisational websites. It is also apparent that publications do not represent activity across the full breadth of Europe and there is, therefore, a need for a broader and more comparative view.

As a result, the scoping review concluded with a number of recommendations for the future reporting of OHP education in Europe, in order to begin to better meet the health needs of the European population:

- Collection of comprehensive, educationally-driven programme-level data on OHP education across Europe;
- Continued publication of discipline-level curricula, in line with the Graduating European Dentist[3] recommendations, in order to facilitate best practice;
- Collection of impact data regarding the implementation of published core and specialty curricula;
- Increased reporting of faculty-level data, including staff numbers, clinical and research experience and educational qualifications;
- Increased reporting of postgraduate/specialty training and CPD, across all disciplines;
- Consistent use of MeSH keywords for publications in dental education;
- Creation of a centralised online toolkit, to facilitate the collection, organisation, display and analysis of pan-European data relating to OHP education.

2 | THE ORAL HEALTH NEEDS OF THE EUROPEAN POPULATION

In 2016 the World Health Organisation (WHO) published its strategy for human resources for health.[13] The overall aim of the strategy was to renew efforts for Universal Health Coverage in order to meet UN sustainable development goals. The strategy makes particular reference to "ensuring equitable access to health workers within strengthened health systems" (p8). Clearly, an important part of this "access" relates to the education/training and deployment of healthcare professionals across Europe. Objective 2 of the strategy references this explicitly, stating that action must "take account of labour

market dynamics and *education policies*; to address shortages and improve distribution of health workers".

The WHO strategy document outlines several milestones that relate to the education and training of OHPs, and these are outlined below (,[13] p9):

2.1 | Milestones by 2020

- All countries have established quality assurance mechanisms for health training institutions
- All countries are making progress on health workforce registries to track health education

2.2 | Milestones by 2030

- All countries are making progress towards improving the course completion rates in medical, nursing and allied health professionals training institutions
- All countries are making progress towards halving their dependency on foreign-trained health professionals, implementing the WHO Global Code of Practice

At present, the milestones in relation to OHP education and training across Europe are at risk of being missed, primarily due to a lack of data reporting. As recommended by the O-Health-Edu scoping review,[2] several measures require immediate implementation in order to:

- Collect the necessary data to analyse the current European position
- Develop a suitable action plan to collect missing data
- Develop a suitable action plan to meet the WHO[13] milestones that form part of global objective 2.

In 2021 the WHO also published a resolution on Oral Health[14] - a global strategy for tackling oral diseases for consideration by WHO governing bodies. The resolution urges member states to "reorient the traditional curative approach" and "move to a preventive promotional approach" to oral health. It also calls on member states to strengthen cross-sectoral collaboration across key settings to promote healthy habits and lifestyles. Following a call for feedback in May 2021, the draft was reviewed. ADEE, which represents the vast majority of the European OHP education institutions, proposed modifications to integrate the consideration of the essential role of the educators, the students, and the educational institutions, in the WHO Strategy for Oral Health.

3 | O-HEALTH-EDU AND A VISION FOR OHP EDUCATION IN EUROPE

O-Health-Edu's vision for the education of OHPs in Europe aligns with the WHO milestones[13] and resolutions,[14] and EU4Health programme[1] objectives - and projects 20 years into the future, to 2040. This longitudinal vision takes a multi-stakeholder perspective to deliver OHP education that acts in the best interests of both students and patients, and sits within the context of a wider strategy for general health.

The vision accounts for the fact that medical curricula today are fundamentally different in content and approach to those written 50–100 years ago.[15,16] As such, there is a greater emphasis on:

- Evidence-based medicine and evidence-based pedagogy
- Integrated curricula, and an outcome-based education
- Student-centred learning
- Staff/Faculty whose primary role is that of an educator
- Inter-professional education
- Accounting for societal needs

There is also a shift away from more traditional, scholarly academic curricula, to curricula which share components that are (amongst others) socially efficient and socially reconstructive.[17] Contemporaneous OHP curricula are already being constructed to align to this vision[3,18] and as such there is already greater emphasis on:

- Meeting the health needs of the population
- Serving the needs of society
- Training for skills required specifically in the workplace
- A focus on competence, capability and lifelong learning
- Deliberate practice and reflection
- Learning-outcome-programmed curricula
- Sustainability
- Empowering OHPs to have vision and to take action

3.1 | Process

Between September 2020 and February 2021, The O-Health-Edu consortium, in conjunction with ADEE, invited an open pan-European consultation on the different elements of the Vision. As well as comprehensive responses from ADEE member institutions and interested individuals, responses were also received from international, national and regional associations, regulators, industrial partners, and student representatives (Table 1). A total of 96 responses were received.

When reviewing each element of the Vision, the O-Health-Edu team took each comment on individual merit. The involvement of multiple stakeholders (educators and clinicians, international and national bodies, regulators and students) has enabled the creation of a shared vision, built through consensus. The vision is represented diagrammatically in Figure 1, Figure S1 and comprises the following elements:

- An integrated curriculum which educates and empowers students of oral health professions to work together collaboratively and synergistically, and as part of a wider healthcare team, in the best interests of their patients.
- A contemporaneous curriculum ensuring clinical and professional capability, which is grounded in evidence-based

TABLE 1 List of international, national and regional associations, regulators, industrial partners, and student representatives who responded to the consultation

International associations
Association for dental education in Europe
European dental hygienists federation
World Health Organisation
Regulatory bodies
French dental council - ordre français des chirurgiens-dentistes
General dental council, UK
Malta medical council
O-Health-Edu quality committee
National and regional associations
Brazilian dental education association
British dental association
Industrial partners
GlaxoSmithKline consumer healthcare
Student representatives
European dental students' association
International association of dental students

Note: Individual and school responses are not included.

education and practise, and which promotes an ethos of lifelong learning.

- A quality-assured curriculum that is responsive to local population demands and variance, whilst maintaining the minimum EU standards that facilitate the mobility of qualified oral health professionals across Europe.
- Inclusive entry criteria, and dynamic curricular approaches that provide effective and accessible education for a diverse range of learners, and their associated learning needs.
- Curricula that embed social responsibility longitudinally throughout programmes, ensuring that OHPs are responsive to the future health needs of their patients, their society, and their environment.
- Clear and demonstrable independent quality assurance of educational programmes that meets a regulatory standard, including evaluation, accreditation and recognition of OHP educators. Each school's students should be considered as a critical component of internal quality assurance processes.
- Curricula that draw on best practice from across the academic community, and that consider the interests of wider stakeholders (such as regulators, postgraduate training institutions, industrial and digital innovations, and health care systems) for better-preparing graduates for the workplace.

FIGURE 1 A Vision for OHP education in Europe [Correction added on 10 September 2022 after first online publication: the orientation of figure 1 was changed and figure 1 was updated as a supporting information figure in this version]

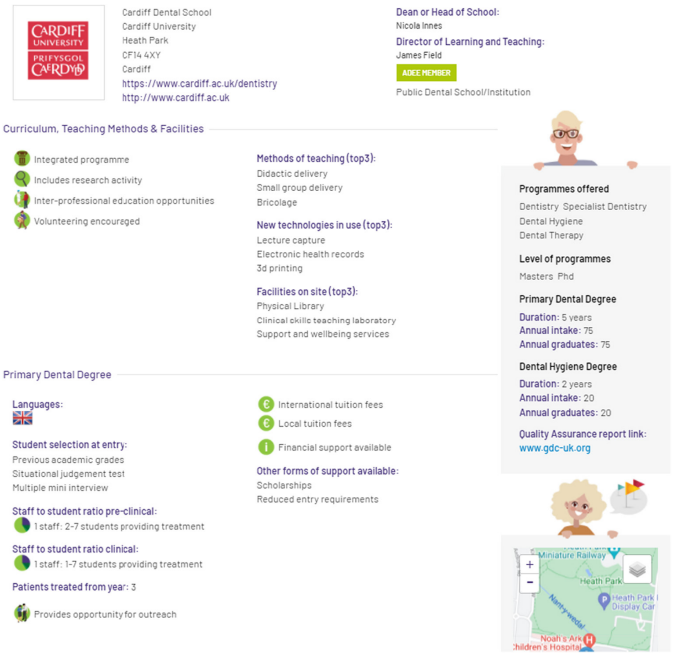

FIGURE 2 An example report card that from the O-Health-Edu data hub (please note that this is an example and may be subject to change. For a live version please visit the data hub directly)

4 | ACCESSIBILITY AND DISSEMINATION

The O-Health-Edu team worked alongside a design company to create a visual which represented the Vision elements in an accessible way. After several iterations it was decided that the most understandable method involved creating a visual that represented a "community of academic practice" with a natural progression through the expected stages of OHP Education. As such, the visual lists the Vision elements to the left, but also represents these diagrammatically on the right. It also became apparent to the team that there was a need to reword the Vision elements for certain user groups using less technical and academic terminology, to make them more accessible and understandable. The user groups that were being discussed included potential students, their parents, schoolteachers, and the general public. The modified vision elements are represented in Appendix 1. Whilst the team, alongside the design company, strived to make the visual as understandable as possible, we also make reference to the online glossary of OHP educational terms, "Articulate" to assist in its interpretation.[19] This can be found, with free online access, at https://o-health-edu.org/articulate.

5 | NEXT STEPS

The next stage of the O-Health-Edu project is to collect comprehensive, educationally driven programme-level data on OHP across Europe. At the time of writing, this process was already underway. This will enable the project to address the milestones outlined in the World Health Organisation strategy for human resources for health,[13] the WHO resolution on Oral Health[14] and other EU Health Programmes. It also improves the visibility of Oral Health Professional programmes across Europe, to all interested stakeholders. This information is accessible at https://o-health-edu.org/ohe-datahub-directory.

The O-Health-Edu data hub presents a "summary card" for each institution that has created a profile (such as that shown in Figure 2). ADEE will invite member schools to sign a charter based on the Vision, and an indication will be made on each report card, for schools that agree to align with the charter—and champion the Vision through the ways in which they deliver their OHP programmes.

ACKNOWLEDGEMENTS

Funded by Agence Erasmus+ KA2 cooperation for innovation and the exchange of good practices / KA203 Strategic partnerships for higher education (2019-2022) Grant/Award Number: 2019-1-FR01-KA203-062894.

CONFLICT OF INTEREST

No conflict of interest has been declared by the authors.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Field J, Dixon J, Davies J, et al.. O-Health-Edu: A vision for oral health professional education in Europe. *Eur J Dent Educ*. 2023;27:382-387. doi: 10.1111/eje.12819

APPENDIX 1

The vision for the intended user groups of students, parents and patients

- A curriculum that teaches students to treat the patient and their needs as a whole, and as a team, rather than learning subjects separately.
- A curriculum which is up-to-date, that makes sure students are safe and ready to work independently in practice, and prepares students for directing their own future learning
- A curriculum that considers the oral health needs of the local population, but also meets national or European standards, so that qualified OHPs can confidently move across the EU to work
- Entry requirements to programmes that consider students' diverse backgrounds, and teaching methods that account for all learner needs
- A curriculum which teaches students to care for their society, the environment, and the health needs of their population within which they work
- A curriculum that is checked by a regulator, and which considers the opinions of students.
- The selection of teaching staff who have the right qualifications and skills
- A curriculum that makes it easier for students to enter the workplace and practice without the need for extra support

ARTICULATE: A European Glossary of Terms used in Oral Health Professional Education.

Introduction

Before collecting data on European educational practices and curriculum structures, the O-Health-Edu project established the need for a common understanding of language to maximise the accuracy of future surveys.

Aim

The Articulate glossary aimed to create a shared understanding of terms and concepts used within OHP education within a European context.

Methodology

The methodology was developed from published glossaries in other fields [318–322]. The process was iterative, grounded in stakeholder consultation, and tested each definition's ‘fitness for purpose’. The terms for inclusion were selected from the first draft of the O-Health-Edu survey and other ADEE curriculum documents [4,24,57,60,146]. These included core pedagogical terms related to programme structure, curricular approaches, infrastructure and educational facilities, preclinical and clinical education, quality assurance, and student selection.

Results

A total of 171 terms were included and used for discussion and definition. The stakeholder consultation included 30 participants from 11 European countries, and the first round resulted in 86 terms being defined as ‘clear’ and 80 ‘unclear’. The ‘unclear’ items were revised, changes were made to improve clarity and ease of understanding, and an open consultation was completed online.

Relevance

Articulate provides a commonality of language for OHP educational terms. As the final step of the O-Health-Edu project is to develop and disseminate a survey across Europe, this glossary will reduce inaccuracies and bias in responses due to a lack of commonality of language and understanding of dental education terminology. Cultural and language variations across Europe could result in inaccuracies in survey responses, and linking the stakeholder-agreed definitions to the survey will reduce bias and may improve completion rates. Additionally, an evidence-based and collaborative glossary will support future work at a European level, and the online version will facilitate regular updates and increase transparency by allowing users to raise queries and receive responses by the task team.

Received: 20 September 2021 | Revised: 15 January 2022 | Accepted: 11 February 2022

DOI: 10.1111/eje.12794

ORIGINAL ARTICLE

WILEY

ARTICULATE: A European glossary of terms used in oral health professional education

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Funding information
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Abstract

Introduction: The Erasmus+O-Health-EDU project aims to gain a comprehensive view of oral health professional (OHP) education in Europe, through the development of web-based surveys and online toolkits. A glossary to facilitate a common language through which academic teams could cooperate and communicate more accurately was identified as a key need within the project. The aim of ARTICULATE was thus to create a shared language, with a European focus, for terms and concepts used in the field of OHP education.

Methods: The methodology was developed from those published for construction of other glossaries with a circular and iterative process: the creation of content and definitions by a group of experts in OHP education, the testing of "fitness for purpose" of the content, and stakeholder consultation. All creation steps were followed by refinements based on testing results and stakeholder comments. The final glossary was then launched as an online resource including a built-in mechanism for user feedback.

Results: The scope and structure of the glossary were mapped out at a workshop with 12 dental education experts from 7 European countries. A total of 328 terms were identified, of which 171 were finally included in ARTICULATE. After piloting with a close group of other colleagues, the glossary was opened for external input. Thirty European Deans or Heads of Education assessed the definition of each term as "clear" or "not clear." A total of 86 definitions were described as "clear" by all individuals. Terms deemed unclear by at least one individual were revisited and changes made to 37 of the definitions. In conjunction with the launch of the glossary, a range of stakeholder organisations were informed and asked to participate in an open global consultation by providing feedback online. Since its launch in June 2021, the ARTICULATE website (https://o-health-edu.org/articulate) has had an average of 500 visits/month. To promote community ownership, forms embedded on the ARTICULATE webpage allow users to give feedback and suggest new terms. A standing taskforce will meet regularly to consider amendments and make changes to ensure that the glossary remains a relevant and up-to-date resource over time.

Conclusion: ARTICULATE is a unique, evolving, online glossary of terms relating to OHP education, created as a resource for all interested OHP educators. The glossary is a key output of the O-Health-Edu project, which relies on a comprehensive vision of OHP education to address the future oral health needs of the European population.

KEYWORDS
dictionary, Europe, lexicon, oral health, professional education, terminology

1 | INTRODUCTION

Across Europe, the oral health of the population shows a high degree of variation within and between countries, related not only to national health care systems but also socio-environmental determinants of health. In view of the complexity of the determinants of health, a well-prepared and adaptable oral healthcare workforce is critical in meeting the current and future needs of the population. Education is a key factor in ensuring that professionals engaged in the provision of oral healthcare have the skills and knowledge required to provide optimal (safe and high quality) care. Across Europe and beyond, a range of professionals including dentists, dental hygienists, dental therapists, dental nurses and clinical dental technicians are involved in different aspects of the provision of oral healthcare and may be referred to as oral health professionals (OHPs). They can be considered more broadly as being "All professionals engaged in actions whose primary intent is to enhance oral health".[1] With the exception of dentists, whose training is regulated in the European Union (EU) directive on the regulation of professional qualifications (2005/36/EC),[2] there is little consensus surrounding the education and scope of practice of other OHPs at a European level. In addition, although the European directive provides overarching guidelines regarding the length and type of training that should be given to dentists, details concerning the content and mode of delivery of primary dental degree programmes are often managed at a national or local level. A recent scoping review revealed a significant gap in knowledge of how education of dentists and other OHPs is implemented and delivered in Europe, with the reporting at the curriculum, programme and faculty levels being both limited and outdated.[3]

Over the past 25 years, there have been several initiatives aimed at describing the delivery of dental education across Europe, including the EU-funded DentEd projects.[4] These initiatives revealed widespread differences in educational philosophy and curriculum content in institutions providing dental education across the continent.[5] This view was reinforced by a recent survey amongst members of the Association for Dental Education in Europe (ADEE) exploring issues such as funding sources, language, student and faculty profile, study hours, and programme characteristics.[6] Whilst differences undoubtedly exist, some of the variation recorded may be attributable to a lack of common understanding of the terms used to describe educational activities in the different European contexts. The multitude of languages spoken across Europe and the use of terms in different ways in different countries may contribute to this. For instance, the question "what is the length of your programme?" may be interpreted as including or excluding preparatory courses and/or obligatory or voluntary postgraduate vocational training. This has lead institutions, even within the same country, to give different answers. It is clear that in order to collect robust data in the future, it is essential that the terms used in data collection exercises are understood in the correct context by both the respondents and the users. As well as being important in supporting the creation of comparable datasets from OHP educators throughout Europe, the use of common terms about OHP education by stakeholders and policymakers also has potential regulatory and legal concerns, since the correct use of guidelines and other decision support tools to enhance the quality of oral healthcare depends on the use of common terms and concepts. The pan-European O-Health-Edu project, funded through the European Union Erasmus+ programme as part of the "Strategic partnerships for higher education" initiatives, is based on a vision of OHP education as a key determinant of the health of European populations. One of the specific objectives is thus to collect data about how OHP education is undertaken in institutions across Europe by means of an online survey. The findings of this survey will be incorporated into a comprehensive data hub, which can be updated in real-time to ensure long-term accuracy and relevance. In the light of the difficulties outlined above with regard to terminology, a needs analysis within the O-Health-Edu project recognised the importance of including an updated and relevant resource, where terms specifically related to OHPs education are clearly defined and explained with a European focus, in the data hub.

Glossaries have now become a common element of web-based "toolkits," aimed at facilitating a common language through which academic teams can cooperate on research or development projects. Many of the documents dedicated to Higher Education at an international level include a comprehensive glossary of terms. Examples include the European Association of Distance Teaching Universities (EADTU) "Glossary of Education terms and EU education references"[7] and the One Health European Joint Programme (OHEJP) glossary to support communication and information exchange between the human health, animal health and food safety sectors.[8] At least two glossaries defining terms used in medical education exist,[9-13] but a literature review and online search revealed that existing resources within the oral healthcare sphere were oriented towards specific thematic areas.[14-18] As an example, the. American Dental Education Association (ADEA) has recently published a "Diversity and Inclusion Terminology appendix"[19] related to strategies to improve recruitment and retention of underrepresented and marginalised faculty by dental schools and allied programmes. However,

none of the published glossaries was deemed broad enough to meet the needs of the O-Health-Edu project. In this paper, therefore, we describe the creation of ARTICULATE, a unique freely available online glossary, developed as part of a toolkit within the O-Health-Edu project. The aim of ARTICULATE is to create a shared language, with a European focus, for terms and concepts used in the field of OHP education as a resource to meet the needs of the OHP education community as well as our partners and collaborators.

2 | METHODS

2.1 | Effective project planning

In October 2019, a workshop involving the twelve members of the pan-European O-Health-Edu working group (international experts in OHP education, from seven different European countries and with a range of European first languages) was held to map out the scope and structure of the glossary and establish a workflow for its creation. During this workshop, it was agreed that the development work should result in an updatable online resource that is freely available to all interested parties. Initially, the glossary, developed in English, should include terms required to provide clarity and better understanding for questions written to collect data regarding OHP education in Europe as well as other core terms used in OHP education. A literature search was performed in PubMed and Google Scholar using the terms "glossary," "lexicon" or "dictionary" to identify relevant articles describing methodology for creation of a glossary. The current methodology was then developed from that published for construction of other glossaries and terminology systems.[20-25] The process was divided into a series of inter-related and iterative work packages aimed at:

1. creating initial content and definitions,
2. analysis and refinement,
3. testing of “fitness for purpose” of the content,
4. stakeholder consultation followed by refinement based on their comments,
5. creation of the final glossary,
6. launch as an online resource including a built-in mechanism for user feedback.

2.2 | Creating initial content and definitions

Initial selection of terms to be included was carried out during the construction of the O-Health-Edu survey regarding the practice of OHP education in Europe. They included basic pedagogical terms related to degrees; programme and curricular approaches; infrastructure and educational facilities; preclinical and clinical education; and quality assurance and student selection as applied to the education of OHPs. To increase the breadth of the glossary and thereby improve its performance as a stand-alone resource for all OHP educators, articles linked to a range of curriculum documents[26-30] were also scanned for supplementary relevant terms. All terms were then uploaded to a communal web platform and members of the working group asked to prioritise the terms for inclusion. Terms deemed as having highest priority by a majority of the group were taken forward for inclusion. Once the preliminary content of the glossary had been agreed upon, each member of the working group was assigned a number of terms to focus on. Definitions were collected from relevant published materials including educational literature (books and journal articles), documents issued by the EU and associations related to OHP education as well as websites and other authoritative terminology resources. All definitions were then collated and uploaded to the web platform where members of the O-Health-Edu working group could leave comments and suggestions.

2.3 | Analysis and refinement of the first draft of the glossary

The collated document on the website was used as a basis for subsequent discussion. The O-Health-Edu working group met regularly online over a period of six months to discuss and refine each of the definitions based on the assimilated suggestions. With the exception of, for instance, protected titles for OHPs defined in EU directives, the group sought to create new definitions either from scratch or by paraphrasing the collected definitions in order to increase their specificity to OHP education and avoid copyright issues. Where there were differences of opinion, a consensus was reached through free and open discussion. The process was iterative and if members of the working group could not agree, further research was conducted as a basis for a new round of discussions until consensus was reached. Particular emphasis was placed on reaching definitions that were both contextual for OHP education and widely applicable in Europe and beyond. All the agreed definitions were then revisited to ensure that they conformed to the agreed style rules for the glossary, which were that they should, wherever possible:

- be succinct,
- give immediate information about what is meant by the term,
- be in the singular form,
- use English UK spelling,
- where possible, not include the term itself,
- where possible, be given in the noun or noun phrase form,
- include common acronyms and synonyms.

2.4 | Determination of fitness for purpose of the glossary

Since one of the purposes of the glossary was to increase understanding of the terms used to describe educational activities in the planned O-Health-Edu European survey of OHP education, relevant definitions were repeatedly tested by the working group and a small

group of external colleagues in the context of the draft questionnaire. This process led to changes being made to both the glossary and the questionnaire itself to ensure as high a degree of clarity as possible. At this stage, in preparation for dissemination, the glossary was named "ARTICULATE—a glossary of terms used in OHP education." A logo was created, and the terms were entered into an online database as a prelude to creation of the digital resource and front-facing web service.

2.5 | Consultation with a group of subject matter experts

The group chosen to pilot the first draft of ARTICULATE was a group of stakeholders who are also subject experts, namely Deans and Heads of Dental Schools from across Europe (defined by the World Health Organisation, *i.e.* 53 countries). For the first round of consultation, individuals registering for the annual online Forum of European Heads and Deans of Dental Schools (FEHDD) meeting in October 2020 were asked to complete a survey concerning the clarity of the glossary terms. The response options to the question "Is the definition of this term clear to you?" were "Clear" or "Not clear." If the response was "not clear," participants were asked to leave a comment. The terms deemed "not clear" by one or more respondents were taken to online consultation at the upcoming meeting. Delegates were assigned, in advance, to 4 groups for discussion of the unclear terms. The sessions were recorded to aid subsequent analysis and members of the working group acted as chairpersons and rapporteurs in each group. Participants were informed of the plan to record the session in advance, and verbal consent was obtained during the session before recording began. The respondents were informed of the approval of the O-Health-Edu project by the Bioethics Committee of the University of Barcelona (Institutional Review Board IRB00C, 03099). The second round of consultation on terms identified from educational documents was undertaken in a similar way but since the FEHDD were already aware of the ARTICULATE project, the process was conducted online, without the workshop element.

2.6 | Dissemination and continued stakeholder feedback

Following final adjustment resulting from the first consultation exercises, all terms were entered into the database serving the online resource. Graphics consistent with the previous O-Health-Edu outputs were created, and a random word generator was added to the ARTICULATE home page in order to make the glossary more inviting and engaging. Feedback forms were embedded to allow users to provide comments and suggestions about specific individual terms or to suggest new terms for inclusion. A variety of potential stakeholders with an interest in OHP education were informed of the launch of ARTICULATE and asked to review and provide feedback: the Federation of European Dental Competent Authorities and Regulators (FEDCAR), the Council of European Dentists (CED), the European Dental Students' Association (EDSA), the Association for Medical Education in Europe (AMEE), the American Dental Education Association (ADEA), the Brazilian Dental Association (ABENO) and EU representation by way of, the European Association for Quality Assurance in Higher Education (ENQA) and the European Dental Hygienists' Federation (EDHF). Moreover, the ARTICULATE website (https://o-health-edu.org/articulate) encourages feedback that will continue to result in changes or additions being made to the terms if needed. This iterative methodology and continuous open consultation processes increase community ownership and allow for continuous refinement of ARTICULATE.

3 | RESULTS

The search for terms for inclusion in ARTICULATE from the O-Health-Edu survey as well as relevant literature yielded a total of 329 potential terms for inclusion (see Figure 1). During the initial round of discussions, 158 of these were eliminated because they were deemed to be outside the scope of the glossary at this stage, they were considered not fit-for-purpose or they had been removed during refinement of the questionnaire. The remaining terms (171), with the exception of "Dentist," "Dental Hygienist," "Dental Therapist," "Dental Nurse/Assistant" and Dental Technologist," which are protected titles under the EU directive 2005/36/EU, were then taken forward for discussion and definition. All members of the group participated in the discussions to ensure the pan-European perspective. After piloting with a close group of colleagues, the glossary was opened for consultation. Thirty participants registered for the FEHDD meetings in October 2020 and May 2021, from France, Georgia, Germany, Ireland, Italy, Macedonia, Portugal, Spain, Sweden, Turkey and UK gave feedback on whether they regarded the definition of each term as "clear" or "not clear." A total of 86 definitions were described as "clear" by all individuals, whereas 80 were identified as "unclear" by at least one individual. The comments received for the terms deemed "unclear" could be grouped into five main themes:

(i) post-COVID considerations (discussion regarding whether more terms relating to the digital delivery of OHP education should be included),
(ii) contemporaneous technological terms (discussion around whether more terms relating to recent technological advances in OHP education should be included),
(iii) names of educational spaces, clinical areas and laboratories (discussion regarding the subtleties of naming phases of the curriculum and physical spaces in which OHP students are educated),
(iv) clarity over how widespread the use of terms is (discussion regarding whether guidance should be provided for terms that are not used ubiquitously throughout Europe – such as vocational training, for example),

FIGURE 1 A diagram showing the workflow for inclusion of terms in ARTICULATE

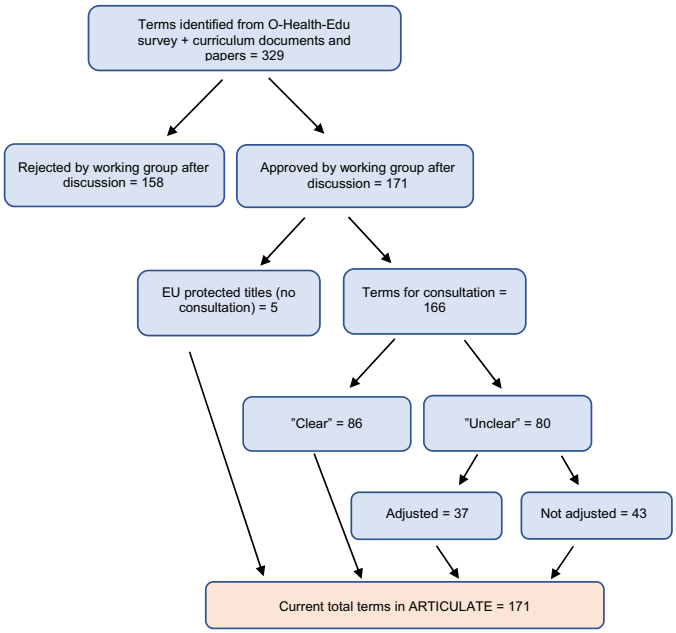

TABLE 1 Some examples of the refinement process for definitions

Term	Initial definition	Comments from consultation	Final definition after refinement
Clinical skills teaching laboratory	A facility that provides a safe and protected environment in which the learner can practise various clinical skills before using them in real clinical settings	"This should also embrace simulation"	A facility that provides a safe and protected simulated environment in which the learner can practise various clinical skills before using them in real clinical settings
Diversity	The condition of being different or varied	"It is not clear what is varied" "I am not clear about what characteristics are different here—please specify the concept"	The range of variation within a group of people that relates to individual characteristics
Practical test	A test designed to determine a person's ability to use their hands in a skilful, co-ordinated way	"A practical test may also assess, for instance, cognitive skills when communicating with a patient"	A structured assessment designed to determine a person's physical ability, either in relation to predefined criteria, or specific skill requirements
Preventative care	Practices designed to prevent oral disease	"Unclear if this is prevention (before disease is present) or includes minimally invasive dentistry (treatment of early-stage disease)"	Nonoperative practices designed to *prevent* oral disease

(v) requests for examples of educational methodologies.

All 80 terms deemed unclear by at least one individual were revisited and changes made to 37 of the definitions (see Table 1 for examples). Following amendment, these were added to ARTICULATE together with the protected title definitions to give a total of 171 terms (see Appendix A). In conjunction with the launch of the glossary, a range of organisations were informed and asked to participate in an open global consultation by providing feedback online. In this context, the ARTICULATE website (https://o-health-edu.org/articulate) had an average of 500 visits per month up to, and including, December 2021.

4 | DISCUSSION

The aim of ARTICULATE was to create a shared language, with a European focus, for terms and concepts used in the field of OHP education. Europe is a vast and enormously diverse area encompassing 44 to 50 countries according to definitions given by the United Nations and WHO respectively (https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf; https://www.euro.who.int/en/about-us). Within this wealth of nations, there are wide differences not only in language but also in the practices used within the healthcare and education systems. This presents a major obstacle to the collection and assimilation of robust pan-European data regarding OHP education, and despite many years of evaluation and discussion about European harmonisation, currently, it is not even known exactly how many institutions across Europe are engaged in education of OHPs. A literature search revealed that the few resources available were not specific to OHP education and were not related to the European situation. Moreover, with the exception of that describing creation of the lactation glossary LactaPedia,[20] there were few papers reporting the methodology used for glossary creation. The focus of this paper was therefore to describe and reflect upon the process used to create ARTICULATE; a key output of the O-Health-Edu project aimed at addressing the future oral health needs of the European population through OHP education.

4.1 | A European context

The pan-European working group approach enabled input from OHP educators with a range of different languages and experiences. The majority of the group were bilingual, speaking English and at least one other European language, which contributed valuable perspective to the discussions. Regular online meetings allowed the group to build a cohesive team and gave sufficient time together for in-depth discussion and dialogue to reach consensus. As the development process evolved, the group gained a better understanding of the many differences and similarities in how OHP education is delivered both within and between the countries represented. Ironically, the process was enhanced by the COVID-19 pandemic as many busy individuals were more available than normal due to home working.[31]

4.2 | Paraphrasing and the application of terms to an OHP education context

From the outset, it was decided by the O-Health-Edu team that, where possible, all terms would be defined independently by the group, prior to the consultation process. Example definitions were taken from a wide range of educational publications to ensure an adequate breadth of content, and these definitions were subsequently collated and paraphrased to form a single concise definition. The final step was to tailor the definition, so that it applied specifically to an OHP education context. The process of establishing independent definitions that are tailored to OHP education was imperative, since this will not only facilitate the collection of robust data from European OHP educational institutions but also ensure that the glossary is fit-for-purpose as a dedicated educational toolkit for all stakeholders in OHP education. As a terminological initiative, ARTICULATE thus differs from, for instance, the MedEdWorld glossary,[13] which is a dynamic source of general information about terms used in medical education compiled from academic references.

4.3 | Establishing terms that translate throughout European and beyond

It became apparent, during both the process of defining terms and stakeholder consultation, that some terms to be defined had very different meanings in different countries. An example of this is the term "vocational education," which can relate to hands-on, job-specific education before, during or after completing a qualification in a higher education institution. Homonymous words were noted as a significant challenge by the members of the O-Health-Edu team, and the process of resolution included referring to relevant literature and open-ended discussions by all experts in the team. Ultimately, consensus was achieved for each term. Referring back to the example, "vocational education" and "postgraduate vocational training" were separated into two distinct terms to provide further clarity, since vocational training may relate to workplace training undertaken as part of the primary degree programme in some countries.

4.4 | The consultation process and development of the online resource

Although the working group comprised professionals from different European countries with experience and expertise in OHP education, consultation with a wider external and multi-stakeholder group was considered an essential part of the project. The first group chosen for this process were the Deans and Heads of European Dental Schools since they represented both the target group for the OHE

survey and a broad group of academics with an interest in educational terminology. They were able to give valuable feedback related to the clarity of the definitions across Europe and the suggestions for improvement resulted in adjustments to many of the terms.

Whilst this relatively high-level approach was necessary to ensure progress within the project, the next step was to open up ARTICULATE to feedback from all stakeholders. ARTICULATE is therefore now available online through the O-Health-Edu website and has feedback forms embedded within it to encourage extension and refinement of the glossary by its users, at any level. The random word highlighting function draws attention to a specific selected terms on the website and it is hoped that this will increase visibility and interest in the glossary.

4.5 | Lessons learned during the creation of ARTICULATE and future perspectives

Overall, the model that evolved for development of ARTICULATE was highly successful, leading to what we regard as a product that is fit-for-purpose. One factor that contributed significantly to the success of the project was the ability to rapidly form a constructive and coherent working group due to the experience that members brought from participation in other taskforce initiatives, including preparation of "The Graduating European Dentist" documents.[29,30] Despite this however, many of the online meetings to reach consensus on all the definitions became rather lengthy. On reflection, formation of smaller working groups to define terms and then report back to the wider constellation would be a more appropriate strategy for future initiatives.

The list of terms included in ARTICULATE is, naturally, not exhaustive—and the O-Health-Edu team do not regard the glossary as a finished project. Although the development of ARTICULATE involved pan-European partners, the online resource is a starting point for continued development by our global OHP educator community, and this will be positively encouraged through wide dissemination of the resource. Moreover, although ARTICULATE is currently available in English, future plans include translation into other European languages.

In order to ensure that structures to support update, extension and refinement are in place, a small taskforce has been identified within the O-Health-Edu team. The group will meet regularly to review feedback in the form of suggested modifications to definitions, proposed new terms for inclusion and identification of errors submitted through the ARTICULATE portal. Amendments will be made following a discussion-to-consensus procedure similar to that used previously. In particular, we are mindful of the requests for exemplification of educational methodologies and recognise the need to be sensitive to the development of new technologies within the area of OHP education. At the end of the O-Health-Edu project, responsibility for this task will pass to a working group within ADEE to ensure that ARTICULATE remains a contemporaneous and comprehensive 'living' resource for OHP educators in the future.

5 | CONCLUSIONS

- The O-Health-Edu consortium identified a need for standard definitions to increase the understanding of terms used in OHP education in different contexts across Europe and beyond.
- A process was developed and successfully used to create ARTICULATE—a unique, online glossary of terms used in OHP education.
- ARTICULATE provides a much-needed resource for OHP educators, which will be kept up-to-date and relevant through expansion and refinement by its community of users.

ACKNOWLEDGEMENT

Agence Erasmus +, Grant/Award Number: 2019-1-FR01-KA203-062894

CONFLICT OF INTEREST

The authors of the manuscript entitled "ARTICULATE: developing a European glossary of terms for use in oral health professional education" report funding from Erasmus+ during the conduction of this study.

DATA AVAILABILITY STATEMENT

The data presented in this manuscript are available from the authors upon reasonable request.

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How to cite this article: Davies JR, Field J, Dixon J, et al. ARTICULATE: A European glossary of terms used in oral health professional education. *Eur J Dent Educ*. 2022;00:1–14. doi:10.1111/eje.12794

APPENDIX A

PREFACE TO ARTICULATE

Oral health professionals are involved in various aspects of oral healthcare provision across Europe. The Erasmus+ funded O-Health-Edu project aims to improve the management of oral health needs in European populations through actions on OHP education, and a starting point is the collection of robust data concerning how this is delivered across the continent. Among the important barriers to a shared understanding of pan-European differences in educational philosophy and curriculum content, are the multitude of languages spoken across the continent and the lack of common understanding about terms used to describe educational activities in the different European contexts. The O-Health-Edu working group therefore identified the development of a resource, where terms used in OHP education are clearly defined, as a key initiative within the project. This led to the development of "ARTICULATE - a glossary of terms used in OHP education." The 171 terms currently included can be broadly divided into the following categories: basic pedagogical terms related to degrees; programme and curricular approaches; pre-clinical and clinical education; infrastructure and educational facilities; quality assurance and student selection.

ARTICULATE was prepared collaboratively by the O-Health-Edu working group, comprising twelve experts in OHP education from seven different European countries. All members spoke English and at least one other European language. Once the preliminary content of the glossary had been agreed upon, we used definitions collected from relevant published materials as the basis for an iterative process of discussion and refinement. Particular emphasis was placed on reaching definitions that were both contextual for OHP education and widely applicable across Europe. A consultation process with a broader group of subject experts as well as a range of other stakeholders, led to further adjustments of many of the definitions.

As well as being presented here, ARTICULATE is also available online at https://o-health-edu.org/articulate. The list of terms is naturally not exhaustive - and the O-Health-Edu team do not regard the glossary as a finished project. Rather, it is a starting point for continued development of a living resource for OHP educators and we encourage feedback through forms embedded within the software that allow the users to provide comments about specific individual terms or to suggest new terms for inclusion. We are already aware of possible future requirements for terms associated with new technologies within the area of OHP education, interest in translation of terms and definitions into other major European languages and an interest in exemplification of educational methodologies. A small taskforce within the O-Health-Edu team will meet regularly to review these issues and we hope that this will ensure that ARTICULATE remains a contemporaneous and comprehensive "living" resource for OHP educators in the future.

ARTICULATE—A GLOSSARY OF TERMS USED IN ORAL HEALTH PROFESSIONAL'S EDUCATION

A

Academic resilience—The ability to continue to effectively work, study and progress through a programme while coping with adverse circumstances.

Accrediting body—An officially recognised organisation that validates or certifies a professional, educational programme or institution against specified standards

Adaptive assessment—A method sensitive to a previous learner's performance, which can be used to set thresholds for future assessments.

Aptitude test—A systematic means of testing a person's innate ability to perform particular tasks and react to a range of different situations.

Asynchronous teaching—Activities which engage a cohort of learners separately and/or at different times to one another.

B

Benchmarking—The process of assessing performance, quality or procedure against a set or expected minimum standard.

Blended learning—A combination of remote and face-to-face, synchronous and asynchronous teaching methods to facilitate learning.

Bricolage—Creative learning through purposeful play.

C

Case-based approach—A method where clinical cases are used to provide a realistic context to allow students to develop and apply their knowledge and reasoning skills.

Clinical assistant—A student giving clinical assistance, to a colleague who is acting as the primary operator.

Clinical decision-making—The process of gathering, interpreting and evaluating patient-based information and the scientific evidence base, in order to make informed choices about patient care.

Clinical dental technician—An oral health professional who can work clinically and technically, to construct and provide dental devices to patients.

Depending on their professional regulation, they may need to work to a prescription from a dentist.

Clinical doctorate—Postgraduate study of 240 European Credit Transfer and Accumulation System units (ECTS), usually as a period of focused specialist-level clinical activity at European Qualifications Framework (EQF) level 8.

Clinical education—The acquisition of knowledge and skills in the context of clinical practice.

Clinical governance—The integrated structures, frameworks and approaches taken by health professionals and organisations to ensure that clinical care is delivered in a responsible, accountable and transparent manner.

Clinical observation—The act of watching a health professional provide care or perform a procedure, within a real or simulated clinical environment.

Clinical skills teaching laboratory—A facility that provides a safe and protected simulated environment in which a learner

can practice various clinical skills before using them in real clinical settings. Synonymous with phantom head laboratory, phantom head clinic and pre-clinical laboratory.

Clinical teacher—A person whose primary role is to teach/support students within a clinical or clinical-simulation environment.

Communication skills—The ability to share information, ideas and feelings effectively with others, *i.e.* fellow students, the clinical team, patients and their families, the community, and other healthcare workers.

Community engagement—Collaboration between higher or further education institutions and their wider communities, to improve awareness of oral health and the oral healthcare professions.

Conceptual reasoning skills—Problem-solving skills that involve reflecting on experiences and drawing on knowledge from other areas, to deepen understanding and inform judgement. Synonymous with "thinking outside the box."

Constructive alignment—The design of learning activities and assessment tasks to support the intended learning outcomes of a programme.

Continuing professional development (CPD) —Engagement in activities that update and broaden knowledge, skills and experience, throughout an oral health professional's career.

Critical thinking—The active, systematic and balanced evaluation of evidence to provide an informed judgement.

Curriculum—Detail of a particular course of study, including learning outcomes, the students' expected educational experiences, assessments and formats for learning.

Curriculum blueprint—A comprehensive plan that maps all elements, *for example* learning activities, assessments and resources, to the learning outcomes so as to ensure consistency throughout the curriculum. Synonymous with curriculum map.

D

Dedicated/special entry programme—An entry programme or entry requirements relating specifically to individuals or groups with particular characteristics.

Dental clinic—The place where oral health professionals (or students) provide oral health care for patients.

Dental Hygienist—An oral health professional who helps patients maintain their oral health by preventing and treating periodontal disease and promoting good oral health practice. Protected title "Dental Hygienist" under the EU directive 2005/36/EU. https://ec.europa.eu/growth/tools-databases/regprof/index.cfm?action=regprof&id_regprof=1073

Dental nurse (assistant) —An oral health professional who provides clinical and other support to registrants (dentists, hygienists and therapists) and patients. Protected titles "Dental nurse," "Dental surgery assistant" under the EU directive 2005/36/EU. https://ec.europa.eu/growth/tools-databases/regprof/index.cfm?action=regprof&id_regprof=12066

Dental School—The unit within an institution that is responsible for teaching and administering dental and oral health professional programmes.

Dental technician—An oral health professional who makes dental devices to a prescription from a dentist or clinical dental technician. Protected titles "Dental technician," "Dental technologist" under the EU directive 2005/36/EU.

https://ec.europa.eu/growth/tools-databases/ regprof/index.cfm?action=regprof&id_regprof=12065

Dental therapist—An oral health professional who carries out limited items of dental treatment direct to patients or under prescription from a dentist. Protected title "Dental therapist" under the EU directive 2005/36/EU.

https://ec.europa.eu/growth/tools-databases/ regprof/index.cfm?action=regprof&id_regprof=1074

Dental virtual reality simulator—A device that allows the user to interact with virtual three-dimensional oral images or environments in a seemingly real way.

Dentist—An individual who has successfully completed basic dental training and is licensed to perform all activities involving the prevention, diagnosis and treatment of anomalies and diseases of the teeth, mouth, jaws and associated tissues. Protected title "Dentist" under the EU directive 2005/36/EU. Synonymous with: Dental practitioner, Dental surgeon, General dentist.

Didactic delivery—The direct delivery of teaching material from teacher to student, typically in lecture format with little student engagement.

Digital radiography—The use of x-ray–sensitive plates or sensors, to capture image data and transfer it to a computer system to store, view and manipulate the image digitally.

Director of Learning and Teaching—An individual typically responsible for the design, implementation and quality assurance of curricula. Synonymous with Director of Education.

Discipline-based/orientated—The teaching of subjects as stand-alone subjects (*i.e* anatomy, physiology, biochemistry), rather than in a thematic way (*e.g.* oral health and disease, the oral ecosystem).

Diversity - The range of variation within a group of people that relates to individual characteristics.

E

E-books—Electronic books: books in digital form, often available online for multiple users.

ECTS—European Credit Transfer and Accumulation System.

EdD (Doctor of Education) —Postgraduate study of 240 European Credit Transfer and Accumulation System units (ECTS), usually as a period of independent research in workplace-based education at European Qualifications Framework level 8.

Education Research—The academic field of study that explores the modalities and effects of education and learning activities.

Electronic health record—A collection of patient health-related information in a digital format.

Electronic portfolio—A digital collection of evidence of an oral health professional's activities, performance and achievements.

Environmental sustainability—Strategic, holistic and long-term approaches committed to minimising the environmental

impact of activities relating to oral healthcare and oral health professional's education.

EQF—European Qualifications Framework.

Erasmus plus (clinical) —A European Union-funded student exchange which happens during the clinical years of an oral health professional's programme.

Erasmus plus (pre-clinical) —A European Union-funded student exchange which happens during the pre-clinical years of an oral health professional's programme.

Ethics—The principles and values that govern an oral health professional's professional practice and behaviour.

Evidence-based practice—The application of the best available scientific knowledge from research as well as clinical practice and expertise, relevant to a patient's needs and context.

Exchange programme—A programme that offers students a period of study at another institution, often in another country, through partnerships such as Erasmus+ or an individual agreement between institutions.

External quality assurance—A process of quality assurance undertaken from outside the institution in question.

F

Feedback—The provision of information regarding a student's performance against an expected standard, with the aim of improving future performance.

Fishbowl learning—A teaching strategy for medium-to-large groups which aims to encourage active listening and reflection on alternative viewpoints. This approach requires the group to be clearly divided into two groups. Groups alternate between being inside the 'fishbowl' (involved in active discussion) and outside the 'fishbowl' (observing the discussion).

Fitness to practice—The ability of an oral health professional or student to provide safe and effective patient care. This ability is based on the knowledge, skills, behaviours and values expected of an oral health professional, which can be self- or externally-assessed.

Fitness to study—The ability of an oral health professional student to adequately engage/ participate with a programme of study and the wider education environment.

Flipped learning—An approach where students acquire knowledge before a synchronous teaching event, and use formal teaching time to discuss, evaluate and apply concepts through interaction with each other and a teacher.

Full-time—Employed by an institution for at least 30 hours (10 clinical sessions, or half days) per week.

G

Gate-keeping activity—An activity (*e.g.* module, course, assessment or programme of study) that regulates student progression, typically relating to patient-based clinical activities.

H

Hidden curriculum—Elements of the curriculum or learning experience which are not explicitly communicated to students, or identified by the teaching staff.

High-school—An establishment providing education up to European. Qualifications Framework level 4. Synonymous with secondary school, college.

High-stakes assessment—An assessment that has an impact on a student's progression at significant points within the programme.

I

Information literacy—The ability to access, manage and use information appropriately, from a variety of sources for research, problem-solving, clinical care and decision-making, and continuing professional. development.

Institution—A place of learning from which students graduate with a recognised qualification. For oral health professionals this would normally be a University (Higher Education), but it may also be a college or other place of Further Education.

Integrated approach—The teaching of subjects in a thematic way (*e.g.* oral health and disease, the oral ecosystem), rather than as individual stand-alone subjects.

Integrated curriculum—A process by which knowledge is primarily taught through an integrated approach for the entire programme of study.

Inter-personal skills—The ability of an individual to interact with others effectively within diverse and possibly complex situations.

Internal quality assurance—A process of quality assurance undertaken *within* an institution.

International EU graduate—A graduate qualifying from an institution in another EU member country (excluding the country in which the institution in question is situated).

International non-EU graduate—A graduate *not* originating from an EU member country.

Interprofessional education—An approach that involves learners from two or more professions, who actively contribute to a collaborative learning environment to improve patient-centred care.

Interview—A structured conversation with a particular focus, where one or more participants asks questions to an applicant.

Intra-oral scanning—A method for capturing direct optical impressions of the intra-oral tissues.

Introduction to healthcare initiative—An initiative to improve awareness and introduce oral health professional roles to young adults, who are still studying at European Qualifications Framework levels 1-4.

J

Junior teaching staff—Teachers recognised as still developing their experience within an academic environment—such as Lecturers, Clinical Fellows, Clinical Lecturers, Clinical Tutors, or visiting Practitioners—involved in the delivery of Oral health Professional's education.

L

Learning needs analysis—A systematic process to collect and evaluate information on what knowledge, skills and competencies an individual or group needs to achieve the intended learning outcomes.

Learning outcome—A series of individual and objective outcomes, with shared ownership between students and staff, designed to facilitate the learning and assessment process.

Learning package—A resource where all necessary learning material for a specific topic is available in a consolidated place, accessible for the duration of the programme of study.

Lecture capture—The process of recording video and/or audio streams of lectures or other synchronous teaching events, and making them available digitally.

Lifelong learning—All learning activity, education and training, formal and informal, undertaken throughout an oral health professional's career that results in an improvement in knowledge, skills and competences.

Longitudinal assessment—The process of assessing specific content repeatedly, or over a protracted period of time.

Longitudinal integration—Integration of teaching material into multiple learning events, throughout a programme.

Low-stakes assessment—An assessment that, in itself, does not *directly* contribute to significant points of progression within a programme.

M

Masters—Postgraduate study of 180 European Credit Transfer and Accumulation System units of which at least 120 must be at European Qualifications Framework level 7. Credits for approved prior learning (APL) may mean that a Masters' programme may be completed in a shorter than usual timeframe.

Multiple mini-interview—An interview format that uses short independent assessments, typically in a timed circuit, to obtain an aggregate score relating to interpersonal, communication, observational and judgement skills.

N

Non-invasive oral care—The provision of oral care that does not involve the irreversible manipulation of hard or soft tissues, such as the delivery of preventive advice, application of topical medicaments and debridement and prophylaxis of the hard tissue surfaces.

O

Objective structured clinical examination (OSCE)—An examination where oral health professional student's skills are tested against pre-defined standards on a circuit of scenarios structured to represent a variety of clinical situations.

Operating microscope—An optical microscope specifically designed to be used by oral health professionals during clinical procedures.

Operative oral care—Oral health treatment that involves the removal or irreversible manipulation of hard or soft tissues, typically under local anaesthesia. Examples include operative caries management, the placement of restorations and periodontal therapy.

Oral health advocacy—An approach that aims to raise awareness, and encourage students, to actively promote oral health issues to wider stakeholders and decision makers.

Oral health professional—A qualified member of the Oral Healthcare team, *i.e.* any one of the following professionals: Dentist, Dental Nurse, Dental Therapist, Dental Hygienist, Dental Technician.

Outreach practice—Dental clinics that allow undergraduate students to provide oral health care to a population geographically distant from the University's main dental school or hospital. On occasion, outreach practices may focus on serving the needs of specific groups of patients. Synonymous with: vocational education in some countries.

P

Part-time—Employed by an institution for less than 30 hours (or 10 clinical sessions) per week

Patient-centered approach–An approach to care that considers patient needs, values and preferences, whilst ensuring that the patient is actively involved in the decision-making process.

Peer-review—The evaluation of a student's scientific, academic, or professional work by other students. Synonymous with peer-assessment, peer-support.

Peer-teaching—An approach where students assist with the instruction of other students.

PhD—Postgraduate study of 240 European Credit Transfer and Accumulation System units, usually as a period of independent research at European Qualifications Framework level 8.

Portable electronic devices—Mobile equipment such as phones, personal computers, laptops or tablets.

Positive discrimination—The practice of *preferential* selection of individuals based on specific protected characteristics.

Postgraduate vocational training—A period of training for graduates of primary dental degree programmes to meet the requirements established by an accrediting, or to work within a particular healthcare system. The existence of post-graduate vocational training is not ubiquitous across Europe.

Postgraduate Certificate—Postgraduate study of 60 European Credit Transfer and Accumulation System units (ECTS) of which at least 40 ECTS must be at European Qualifications Framework level 7.

Postgraduate Diploma—Postgraduate study of 120 European Credit Transfer and Accumulation System units of which at least 90 ECTS must be at European Qualifications Framework level 7. Credits for approved prior learning (APL) may mean that a diploma may be obtained in a shorter than usual time frame.

Practical exercise—A defined and purposeful learning activity that involves physical processes or purposeful play.

Practical test—A structured assessment designed to determine a person's physical ability, either in relation to pre-defined criteria, or specific skills requirements.

Preventative care—Non-operative practices designed to *prevent* oral disease. Synonymous with preventive care.

Primary dental degree programme—A course of study resulting in qualification as a dentist. Synonymous with BDS, BChD.

Private funding—Funding received from non-government sources.

Problem-based learning—A student-centred teaching philosophy in which the learning is driven by the students solving an authentic problem, often in small groups with a facilitator.

Productive failure—A learning approach whereby students attempt to solve problems without explicit initial instruction, followed by discussion and reflection, that makes future attempts more productive. Synonymous with productive learning.

Professional accreditation—A process that results in the registration or licensing of an individual to practice in a particular oral health profession.

Professional development plan—An outline or schedule, made by an oral health professional of planned participation in events or processes which support their training or career development goals/needs.

Professionalism—Demonstration of commitment to a set of values, behaviours and relationships expected of an oral health professional, which help to maintain public trust in the relevant profession.

Programme—A recognised course of study that provides a coherent learning experience and normally leads to a qualification

Protected characteristics—Characteristics by which individuals are protected against discrimination: age, culture, diversity of background and opportunity, disability, gender, language, religion and sexual orientation.

Purposeful play—Dedicated activities which allow learners to explore and experience the behaviour of materials, equipment and processes in a safe and protected environment.

Q

Quality assurance—The systematic evaluation of oral health professional's education, to improve quality, and ensure that programme standards are sufficient to meet necessary institutional and/or external regulatory requirements.

R

Reduced entry requirement—A lowering of the standard requirement (financial or academic) to allow entry onto an oral health professional programme. Synonymous with contextual offer.

Reflective portfolio-based approach—A methodology where students are required to record longitudinal information about educational activity, often supported by a reflective framework.

Reflective practice—A process of thinking deeply and carefully about professional practices, so as to engage in a process of continuous and lifelong learning.

Research activity—*Active* participation in clinical, epidemiological, experimental, or educational research.

Research laboratory—A facility where students or staff can engage in experimental or applied research.

Role-play—A simulation methodology where students or educators enact roles and character presentations, to illustrate scenarios relevant to the educational or clinical setting.

S

Safe-beginner—A graduating oral health professional who can demonstrate the range of capabilities expected within their scope of practice whilst still developing skills in, and through, self-reflection and lifelong learning.

Scholarship—A grant or payment made to support a student's education, which does not need to be paid back to the donor.

Synonymous with bursary, award, stipend. Homonymous connection: The term in this context should not be confused with its use in "The *Scholarship* of Teaching and Learning."

Scope of practice—The range of procedures an oral health professional is permitted to perform under their specific level of professional registration/ regulation.

Self-assessment—The evaluation of oneself or one's actions, attitudes or performance in relation to pre-defined objective criteria.

Self-awareness—The ability to reflect on one's own characteristics, including attitudes, skills and behaviours.

Senior teaching staff—Teachers recognised as holding significant experience within an academic environment—such as Professors, Associate Professors, Readers, Senior Lecturers, and Senior Clinical Teachers—involved in the delivery of oral health professional's education.

Shadowing—Following someone and observing in order to learn.

Signposting—Providing directions to the learner about the aims or progress of an activity in relation to the intended learning outcomes.

Situated learning—Learning through participation and reflection on contextual, cultural, and authentic real-life activities.

Situational judgement testing—A method of evaluating a person's responses and judgements, in relation to a range of specific scenarios.

Small-group delivery—An educational approach that involves students working together in groups of up to 8, to undertake tasks and achieve specific learning outcomes.

Social accountability—The responsibility of an oral health professional to raise awareness of their community's needs, and to act in their best interests, particularly in relation to the underserved and vulnerable populations.

Social determinants of health—"The conditions in which people are born, grow up, live, work and age. These conditions influence a person's opportunity to be healthy, his/her risk of illness and life expectancy." Defined by The World Health Organisation: https://www.euro.who.int/en/health-topics/health-determinants/social-determinants#:~:text=Social%20determinants%20of%20health%20are,of%20illness%20and%20life%20expectancy.

Social skills—Attitudes and abilities relating to communication and interactions with others.

Specialist dentist—A dentist who has successfully completed a nationally-recognised training programme and is registered as a specialist with the national regulator or equivalent. Synonymous with Specialist Dental Practitioner.

Spotter test—A formative assessment that requires students to interpret visual artefacts (*e.g.* images, specimens) —typically in relation to anatomical structures, pathological conditions or diseases. Synonymous with Steeplechase assessment.

Stakeholder—An individual, group, or organisation, recognised as being affected by the decisions of another organisation; and who may provide insight and influence to shape such decisions.

Stand-alone school—A dental school that governs itself, with no parent institution.

Standard setting—The process whereby clear and defined boundaries of performance are set for an assessment

State examination—A licensing examination that future oral health professionals are required to pass to be allowed to register to work in their profession, after graduating from the primary degree programme. Typically, a licensing examination would be a national requirement.

State funding—Funding received from government sources. Synonymous with Public funding.

Storytelling—A tool that uses narratives (stories) to enable students to develop the skill of critical reflection, and to develop as reflective practitioners. Synonymous with Narrative pedagogy.

Student preparedness—How "ready" a given student is to engage in educational or clinical activity.

Student satisfaction—A student's perception of how satisfied they are with their educational experience and outcomes.

Support and well-being services–Services providing general information, advice and welfare support for students and staff of the institution in relation to, *for example* disability, mental health, counselling and educational opportunities.

Synchronous teaching—Activities which engage a cohort of learners together, at the same time (*i.e.* a live teaching event).

T

Tacit learning—Learning directly through observing someone who is drawing on their own personal experiences, which are difficult to rationalise/explain.

Teachback—A method of assessing if a student understands a concept by asking them to explain it back to an educator or group.

Teaching excellence—A multi-dimensional concept integrating approaches that contribute to good student learning experiences and outcomes, either through direct influence on the students, or indirectly through staff development or institutional policy.

Teaching staff—Persons whose primary function is to provide teaching within the institution. Synonymous with Faculty.

Teamwork—The coordination and implementation of tasks and activities between different healthcare professionals.

Technical skills teaching laboratory—A facility that provides a safe and protected environment in which the learner can practice technical skills before using them to create devices for patients. Synonymous with Prosthetic laboratory, Technical laboratory, Dental Technology laboratory.

Term of office—The period over which a member of staff holds a particular governance position.

Threshold concept—A topic within a curriculum that, when understood, results in fundamental changes in perception and practice of other parts of the subject/discipline.

U

Under-represented group—A subset of the population that is inadequately represented in relation to oral health professional education.

University level pre-dental programme—A course of study within higher education aimed at preparing a student for entry to a primary dental degree programme. Synonymous with Foundation programme.

V

Vertical integration—The coordinated, purposeful and planned linkage of curriculum elements to learning activities so that basic skills and knowledge are developed and reinforced across a whole programme in a progressive manner, *for example* the integration of basic sciences and clinical practice.

Virtual campus—The range of online facilities, services and learning resources provided by a higher education institution.

Virtual learning environment—An educational online platform that contains digital resources related to a course or programme of study.

Vocational education—The provision of hands-on, job-specific education and experience in the workplace that prepares an oral health professional student to work independently in a healthcare setting.

Volunteering—The provision of services within the wider community by oral health professional students, for no financial gain, as a recognised part of their studies.

W

Whistleblowing—The act of making a protected disclosure of information about actions that are unlawful, or not in the best interests of others.

Widening participation—Measures aimed at addressing the discrepancies in higher education opportunities between different groups within a population. Synonymous with Widening access.

Workplace-based assessment—An evaluation based in a normal practice environment, often used to assess professional competence.

Written examination—A form of assessment that requires students to respond in writing. The format can be paper-based or digital.

3

3D-printing—A process by which it is possible to build three-dimensional objects from a computer-aided design model.

A Viewpoint into the Current State of Oral Health Professional Education in Europe: Part 1: Programme-level Data

Introduction

The scoping review provided evidence and recommendations for developing an exploratory approach to data collection of European OHP education practices. As surveys are cross-sectional and, therefore, quickly outdated, a modification to this methodology was developed in the form of a data hub. A data hub houses a survey within a webpage but allows all respondents to be data controllers and update their responses over time. The datahub was placed on the O-Health-Edu webpage (https://o-health-edu.org/report-cards-map), and schools were invited to sign up and provide data on their programme, educational practices and curriculum structure. Due to the length and scope of the responses, the data was presented in two publications, part 1 and part 2.

Aims and Objectives

This series of publications aims (i) to present data regarding OHP education from institutions representing various geographical locations across Europe and (ii) to establish commonalities and trends. Part 1 of this series seeks to explore programme-level data for Primary Dental Degree programmes, Dental Hygiene, and postgraduate education.

Methodology

A Delphi-type approach with project members was used to develop a 91-item questionnaire, which included direct links to the Articulate glossary for each question. The content of the questionnaire was based on the findings of the scoping review and previous ADEE curriculum documents and topics of interest at regional meetings. The questionnaire was uploaded onto the O-Health-Edu webpage to create the datahub. Piloting was completed by project members and an external steering committee to ensure face and content validity before dissemination of the definitive survey. A consultation of the final draft of the questionnaire was completed with key stakeholders from across

Europe. All ADEE-registered OHP schools were invited to participate by email, and the datahub was also promoted at face-to-face academic meetings and on social media. Descriptive statistics were performed on all data using SPSS Statistics.

Results

Seventy-one responses were received from 25 European countries, equivalent to 49.3% of ADEE members. The programme-level data presented includes programme length, programme funding and fees, extra costs for students, student numbers and demographics, student admission and selection processes, the language of study and permission to practice after graduation, and postgraduate programmes offered. Most programmes (76%) are five years in duration, with a smaller proportion of six-year programmes (23%). There was a significant range of student numbers across institutions, with most (57%) accepting between 61 and 150 students. Dental hygiene student numbers appear generally smaller than dental programmes. Student selection was performed mainly by a national body (41%) and universities (36%). Only 19% of respondent dental schools selected their students. 72% of responding schools are publicly funded, and a range of tuition fees were noted. Most students (76.1%) can practice immediately upon graduation.

Relevance

As far as the authors know, this data collection process is the first attempt to construct a comprehensive overview of the current programme and curriculum structures of European OHP education. The datahub presents a live and modifiable resource that allows institutions to amend their data as practices change. Transparency and visibility of OHP practices are essential for all key stakeholders, the European population, prospective students and academics. A realistic understanding of the current state of OHP education in Europe will allow academics, researchers, and organisations to develop tailored resources for the field. The improved contextual understanding of programme structure derived

from this work will improve the applicability of the outputs that are developed in the subsequent stages of this research project.

Received: 8 August 2023 | Revised: 18 October 2023 | Accepted: 18 December 2023

DOI: 10.1111/eje.12989

ORIGINAL ARTICLE

WILEY

O-HEALTH-EDU: A viewpoint into the current state of Oral Health Professional education in Europe: Part 1: Programme-level data

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Erasmus+

Abstract

Introduction: Current legislation leaves Oral Health Professional (OHP) education open to wide interpretation and may result in significant variation in educational practice and resultant professional attributes across Europe. Data regarding the current state of OHP education across Europe is limited. The aim of Part 1 of this series is to provide programme-level data for Primary Dental Degree Programmes, Dental Hygiene and Postgraduate Education.

Methods: A 91-item questionnaire was developed following the Delphi method. The questionnaire and the Articulate glossary of OHP education terms were developed concurrently to facilitate a common understanding of language. Piloting was performed in multiple stages and included institutions internal and external to the research group. The questionnaire was uploaded online and converted to a data hub, allowing dental schools to control their own data and update the data provided whenever they wish. All ADEE member schools ($n = 144$) were invited to provide data. Forty questions relating to school details, Primary Dental Degree Programmes, Dental Hygiene and Postgraduate Education were included in this part of the series.

Results: Seventy-one institutions from 25 European countries provided data between June 2021 and April 2023, which represents a response rate of 49.3% of ADEE members. Programme-level data for Primary Dental Degree Programmes, Dental Hygiene and Postgraduate Education is presented including programme length, funding, languages and fees, student numbers and demographics, student admission and selection processes and permission to practice after graduation.

Conclusion: This series of papers, as far as the authors are aware, are the first attempts to build a comprehensive picture of the current state of OHP education in Europe. A comprehensive view of the state of OHP education in Europe is not yet *available* but the O-Health-Edu data hub provides a means for all education providers

in Europe to contribute data to reach this goal. It is anticipated that the data hub will be updated and *built* upon over time to continually establish a clearer picture of the state of OHP education in Europe.

KEYWORDS
dental education, dental hygienists, Europe, Oral Health Professionals, survey

1 | INTRODUCTION

The education of Oral Health Professionals (OHPs) is extremely important as, through developing the future workforce, it directly influences the adequacy and efficiency of oral health care services delivered to populations.[1]

1.1 | Regulation of Oral Health Professional education in Europe

OHP education is an umbrella term that reflects the diversity of the Oral Health workforce. It refers to qualified members of the Oral Healthcare team and usually includes dentists, hygienists, therapists, assistants and clinical dental technicians, although regulation across European countries varies.[2] The term "Dentist" is a protected title and the EU directive 2005/36/EC on the recognition of professional qualifications defines the education of dentists across Europe.[3] Currently there are no European directives to outline the education of other OHPs, including dental hygienists; this is managed at a national level, often with large variation.[4]

The directive for the education of dentists defines the length and level of study and the credits required to graduate in the EU and other recognised countries.[3,5] The Annex V3/5.3.1 of the directive defines a "study programme for dental practitioners".[3] It has been acknowledged that this annex does not reflect current practice in dental education with the Council of European Dentists (CED) and the Association for Dental Education in Europe (ADEE) proposing changes.[6] The limited information communicated in existing European regulations leaves dental education open to wide interpretation and may result in significant variance in practice across Europe.

1.2 | European OHP education – Current climate

There is limited knowledge of the current state of OHP education across Europe. This is emphasised by the fact that there is no data confirming the exact number of OHP schools across the European continent. The most recent Council of European Chief Dental Officers (CECDO) database recorded 220 'dental' schools and the CED's EU Manual of Dental Practice identified 200.[7,8] However, these sources only include 34 EU/EEA members and the World Health Organisation's (WHO) broader definition of Europe comprises 53 countries.[9] Previous studies to provide data on programme structures and educational practices are limited at a European level, as evidenced in two recent reviews.[10,11] Shanley et al.[12] published one of the first reports on educational practices from dental schools across Europe in 1997, although it is now considered largely outdated and had a limited sample size. The CED's EU Manual of Dental Practice and the CECDO database provide data regarding the number of public and private institutions, annual intakes, course duration and percentage of female graduates.[7,8] Naturally these two documents focus on the OHP workforce and therefore only gather educational data that provides insight into future workforce demographics. For dental hygiene, Luciak-Donsberger and Eaton[13] published data from a European survey regarding programme structure, curricula and professional regulation in 2009. Other educationally focused data for dental hygiene exist but these are mostly outdated.[14–16]

It is a concern that European-wide data is not available to facilitate visibility and transparency of educational structures and practices. Higher education institutions have an important role in protecting the population by ensuring all OHP graduates are safe to practice. As qualified dentists can move freely to live and work across many European countries, any variances in graduate skill-sets may result in inequities in both quality of care and healthcare coverage.[10]

1.3 | The O-Health-Edu project

O-Health-Edu is an EU-funded collaborative Erasmus + project that commenced in 2019. The overarching aims of the project are to better understand the existing state of OHP education in Europe and to develop a common vision of this education and support changes by 2030. The project commenced with a scoping review to uncover current reporting of OHP education in Europe.[10] The review identified four broad reporting themes:

- Dental education at a programme-level
- Dental education at a discipline-level
- Other OHP education
- Postgraduate education and continuous professional development (CPD)

The scoping review concluded that there is limited reporting of current educational practices in OHP education. Additionally, whilst there are numerous publications that provide recommendations

on teaching practice, there is little data regarding implementation of these practices. Recommendations for future reporting of OHP education were provided including a call for the collection of comprehensive, educationally driven programme-level data on OHP education across Europe. Further work from the O-Health-Edu project resulted in a consensus-agreed vision for OHP education in Europe[17] and Articulate – a glossary of OHP education terms.[2]

To achieve the aims of the O-Health-Edu project by understanding the current state of OHP education in Europe, a data collection process was required. Surveys are a common instrument used to collect data in dental education due to their relative ease of use and the ability to cover wide geographical areas.[18,19] However, surveys are cross-sectional, and data is controlled by the administrator of the instrument. The partners of the O-Health-Edu project decided to act upon the recommendations from the scoping review, to create a centralised online data hub to facilitate collection, organisation and analysis of pan-European data relating to OHP education.[10] This still conforms to accepted standards for survey methodologies but enables respondents (in this case OHP institutions) to be data controllers and therefore update the information provided when necessary. The online data hub also provides information that is visible to the public in the form of a European map and "report cards" (Figure 1). The map and report cards are accessible via the O-Health-Edu website (https://o-health-edu.org/report-cards-map).

The aim of this two-article series is to present data regarding OHP education from institutions representing a variety of geographical locations across Europe and to establish commonalities and trends. A specific objective of this paper is to provide programme-level data for Primary Dental Degree Programmes, Dental Hygiene and Postgraduate education.

2 | METHODS

This study received ethical approval from the Ethics Committee of the Universitat de Barcelona (IRB00003099, 5th October 2020).

2.1 | Instrument development and piloting

A 91-item questionnaire was developed by the O-Health-Edu project team. The topics of interest were conceptualised during an in-person meeting and stemmed from existing literature and the experiences of the group and ADEE. The questions were separated into the following groups:

- General Information on Survey Respondent (6)
- School Details (14)
- Programmes Offered (10)
- Primary Dental Degree Programme (20)
- Curriculum (14)
- Facilities (6)
- Quality Assurance (5)
- Dental Hygiene Programme (16)

The design phase of this ad-hoc questionnaire followed the Delphi method. The purpose of this method is to gather expert opinion on a specific topic and establish consensus by subjecting experts to successive waves of questioning.[20] Thus, the design of the questionnaire was carried out with a group of 11 European experts (O-Health-Edu project members that represented a range of geopolitical contexts and locations) who were iteratively solicited to reach a consensus for an initial version of the questionnaire. At each stage, a given version of the questionnaire was discussed with all experts and the opinions of each person and/or the justifications for the choices made or to be made were gathered. From then on, experts were invited to work together to come up with a new version according to the opinions collected, and this repeated until a final version was unanimously agreed. The objective was to develop questions that were understandable and valid for all respondents, regardless of their country of origin, the health care system in place in the country or the context of OHP education.

The content of the questionnaire was shaped by the scoping review, previous curriculum documents and topics of interest raised at ADEE meetings.[10,21–30] The writing of the Articulate glossary of OHP education terms occurred concurrently to the questionnaire development and all key terms within the questionnaire were included in the glossary.[2] This allowed consensus-agreed definitions to be linked to each question to facilitate a common language and uniformity in the understanding of key terms.

The questionnaire was first tested for face and content validity with the members of the O-Health-Edu steering & quality committee (17 members). The data and comments from this phase were analysed to develop an updated version of the questionnaire. A second stage of piloting occurred with a second group of 35 European OHP academics. Respondents were invited to complete the questionnaire and to evaluate the language used and the validity of the questions. Moreover, before the survey was distributed, a consultation phase was carried out with OHP stakeholders including CED (Council of European Dentists), FEDCAR (Federation of Regulatory Authorities), EDSA (European Dental Student Association) and ADEA (American Association of Dental Education). These pilot phases allowed for the development of a final version of the questionnaire that ensured quality and ease-of-use.

The questionnaire was subsequently uploaded onto the O-Health-Edu website (https://o-health-edu.org/ohe-datahub-directory) and developed into a data hub. The data hub allows institutions to access and control their own data by creating an account and completing the questionnaire online. Users (designated contacts from OHP institutions) can answer and edit any responses at any time to keep information up to date. An additional pilot was performed on the web-based system to ensure ease-of-use.

A total of 40 questions from the 91-item questionnaire are included in this part of the series as they related to school details (1), Primary Dental Degree Programme (18), Dental Hygiene (16), Postgraduate Education (5). All questions were in English; no

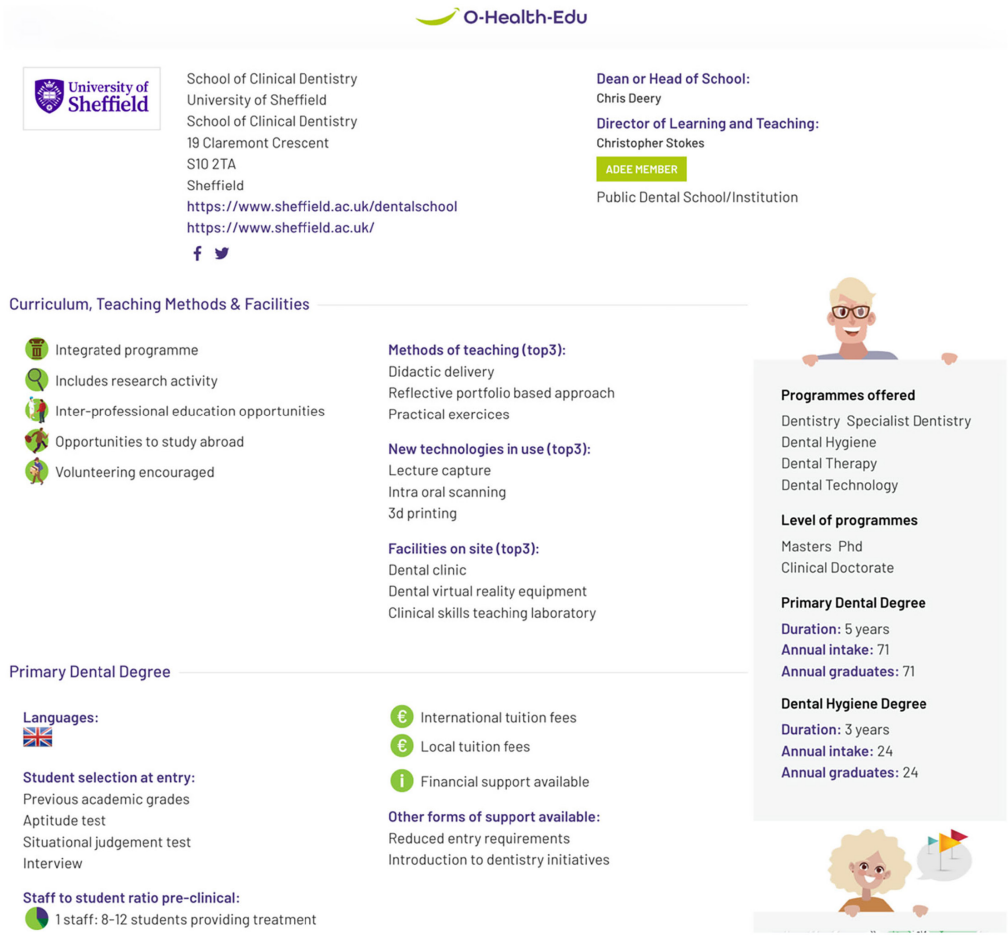


FIGURE 1 A screenshot of the report card from the University of Sheffield.

translations were made available. The questions used in this manuscript can be found in Appendix S1.

2.2 | Recruitment and data collection

All OHP schools in Europe were eligible to provide data for their institution, however as the exact number of OHP schools is not known, reaching all schools was impossible. All ADEE registered schools ($n = 144$) were sent an email invitation to register on the O-Health-Edu website and to provide educational data for their institution. Institutional contacts (either the Head of School/Dean or their designated contact) provided data for their institution. Emails were followed up regularly and ADEE members were supported to register during annual ADEE meetings. The initial objective was to obtain a response rate of 50% of ADEE member schools. Thus, efforts were made to increase the response rate. The survey was repeatedly offered by email to the ADEE member list as well as during face-to-face academic and research meetings using tablets. The distribution of the survey was also promoted on social media (LinkedIn, Twitter, Facebook and Instagram) from the accounts of ADEE, the O-Health-Edu project, project member accounts and European partner organisations.

Data from non-ADEE member institutions was included but these institutions were not directly invited due to challenges in locating them and finding relevant contact details. Technical experts and experienced academics were available if any institutional contact had any queries during data submission. Whilst data collection continues

indefinitely for the data hub, a cut-off period of 17th April 2023 has been used for the purposes of the data reported in this manuscript. Any data provided from institutions outside of the 53 European countries set out in the WHO definition of Europe was excluded.

2.3 | Statistical analysis

Descriptive statistical analysis was performed using the IBM SPSS Statistics program (version 26) to present data in counts and percentages. Microsoft Excel 2017 was used to represent the results in tables and graphs. Owing to the small and non-representative sample of the many schools throughout Europe, few comparisons between groups of schools were made.

3 | RESULTS

A total of 71 institutions from 25 countries provided complete data between 8th June 2021 and 17th April 2023. This represents a response rate of 49.3% of ADEE member institutions. All countries represented in the data are included in Table 1. Countries with the most respondents were France and Spain, with 11 and 10, respectively. Eight schools from each of Great Britain, Italy and Turkey also participated. Programme-level data for OHP programmes will be presented in two sections: (i) Primary Dental Degree Programmes (71 submissions) and Dental Hygiene (25 submissions) and (ii) Postgraduate Degree Programmes (64 submissions).

To facilitate organisation of content and ease of reading, the results have been categorised into the following:

Primary Dental Degree and Dental Hygiene Programmes:

- Programme Length
- Programme Funding and Fees
- Extra Costs
- Student Numbers and Demographics
- Student Admission and Selection
- Language of Study
- Permission to Practice after Graduation

Postgraduate Education

- Language of Study
- Programme Fees
- Postgraduate Study Programmes

3.1 | Primary Dental Degree and Dental Hygiene Programmes

In Articulate, a Primary Dental Degree Programme (PDDP) is defined as "A course of study resulting in qualification as a dentist".[2] The definition or scope of practice for dental hygiene (DH) is not as well-defined but Jongbloed-Zoet et al.[4] established two core activities for dental hygienists in Europe: education and promotion activities relating to preventive oral health and examination, diagnosis and provision of preventive dental care.

3.1.1 | Programme length

More than three-quarters of dental schools ($n = 54$) deliver their PDDP over 5 years, 16 schools deliver it over 6 years, and one school in 4 years (Table 1). Institutions within the same country mostly align in programme duration although a few exceptions were noted. Twenty-five of the 71 respondent schools also provided data about their DH programmes. The most common programme duration is 3 years (68%) and to a lesser extent 2 years (20%) (Table 1).

3.1.2 | Programme funding and fees

The majority of respondent OHP schools (71.8%) are publicly funded, with 12.7% privately funded and 15.5% of schools receive a combination of state and private funding. When asked to provide information regarding the fees associated with PDDP and DH programmes, between 14 and 18 schools selected the not applicable option and the rest selected the fee range pertaining to their school. Data for tuition fees across all programmes are included in Figure 2. Of those schools, approximately 50% request fees of less than €5000 per year for home students in pre-clinical years, with the remainder requesting up to €15 000 except for one school which charges fees between €20 000 and €25 000 per year. In clinical years, almost 50% of schools still request fees of less than €5000, but three schools charge between €20 000 and €25 000. For international students, the fee ranges are distributed across all response options; however, 12.7% of schools request fees of greater than €20 000 in pre-clinical years and 18.3% request greater than €20 000 in clinical years. The home fees associated with DH degree programmes are less than €15 000 per year, with 60% requesting less than €5000. The international fees range from €500 or less to a maximum of €50 000, although 40% of schools still request fees less than €15 000.

3.1.3 | Extra costs

In addition to tuition fees, many schools also reported imposing extra costs associated with dental materials and/or equipment use for their PDDP (Table 2). The median amounts charged are €1000 for pre-clinical activities and €1500 for clinical activities in total. Eighteen schools offer financial support for pre-clinical activities and seven offer support for clinical activities. Further, five schools report that

TABLE 1 Duration of primary dental degree and dental hygiene programmes by country.

	Primary Dental Degree Programme				Dental Hygiene Programme					
Country	5 years	6 years	Other	Total	1 year	2 years	3 years	4 years	Other	Total
Belgium	1	0	0	1						
Croatia	0	1	0	1						
Cyprus	1	0	0	1						
Denmark	0	1	0	1	0	0	1	0	0	1
Estonia	1	0	0	1	0	0	1	0	0	1
France	11	1	0	12						
Georgia	1	0	0	1						
Germany	1	0	0	1						
Greece	1	0	0	1						
Hungary	2	0	0	2	1	0	0	0	0	1
Ireland	2	0	0	2	0	2	0	0	0	2
Israel	0	1	0	1	0	1	0	0	0	1
Italy	0	8	0	8	0	0	7	0	0	7
Lithuania	2	0	0	2	0	0	0	1	0	1
Latvia	1	0	0	1	0	1	0	0	0	1
Malta	1	0	0	1	0	0	1	0	0	1
Netherlands	0	1	0	1						
Norway	1	0	0	1	0	0	1	0	0	1
Poland	0	1	0	1						
Portugal	3	0	0	3	0	0	1	0	0	1
Romania	0	1	0	1	0	0	1	0	0	1
Spain	9	1	0	10						
Sweden	1	0	0	1						
Turkey	8	0	0	8						
United Kingdom	7	0	1	8	0	1	4	0	1	6
Total	54	16	1	71	1	5	17	1	1	25

Note: Of the Other responses for PDDP: 1 respondent = 4 years graduate entry programme. Of other responses for DH programme: 27 months.

there are extra fees associated with dental materials and/or equipment for their DH programme (Table 2); and of these, four state that financial support is available to help students pay these fees.

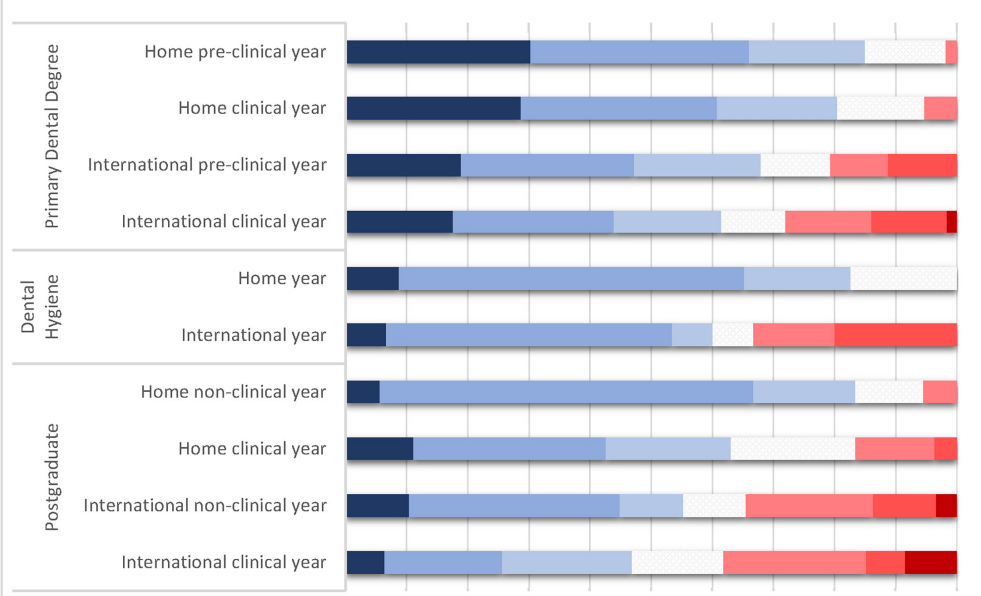
3.1.4 | Student numbers and demographics

Over 57% of schools accept between 61 and 150 students per year in their PDDPs (Table 3), and over 56% of schools estimated their percentage of female graduates to be between 51% and 70% (Table 4). Indeed 80% of schools estimated more than half the graduating class will be female. In contrast, two schools estimate 10% or less of their graduates will be female. For DH programmes, class sizes appear comparatively smaller with 92% of schools accepting 40 or fewer and 48% accepting 20 or fewer students per year (Table 3). Eleven schools estimated that more than 90% of their DH graduating class is female, and 23 estimate their female graduates outnumber their males (Table 4). In contrast, two schools estimate that females will only make up 21%–30% of graduates.

With respect to the nationality of graduates, the mean and median percentage of PDDP graduates of those from other EU countries outside of where the school is located is 7.7 (CI: 4.5, 10.9) and 2.3. The mean and median percentage from non-EU countries is 13.9 (CI: 7.9, 19.9) and 5.0.

3.1.5 | Student admission and selection

Student admission numbers in PDDPs are set by national or regional bodies for most schools (73.2%), while they are set locally by the university for the rest. A similar majority of schools (76.1%) recruit most of their students from secondary school, while 19.7% recruit mostly from university level pre-dental programmes and 4.2% have other recruitment pathways (Table 5). Student selection is conducted by different organisations but most often by a national body (41.3%) or the university and/or partner university (36%) (Figure 3). Dental schools select their prospective students in only 19% of respondent institutions.



	Postgraduate				Dental Hygiene		Primary Dental Degree			
	International clinical year	International non-clinical year	Home clinical year	Home non-clinical year	International year	Home year	International clinical year	International pre-clinical year	Home clinical year	Home pre-clinical year
0-500€	3	3	6	2	1	2	10	10	16	16
501-5000€	9	10	17	22	7	13	15	15	18	19
5001- 10000€	10	3	11	6	1	4	10	11	11	10
10001- 15000€	7	3	11	4	1	4	6	6	8	7
15001-25000€	11	6	7	2	2	0	8	5	3	1
25001-50000€	3	3	2	0	3	0	7	6	0	0
≥ 50000€	4	1	0	0	0	0	1	0	0	0

FIGURE 2 Comparison of tuition fees across programmes, Home or International, clinical and non-clinical years.

TABLE 2 Extra costs associated with dental materials and/or equipment in Primary Dental Degree ($n = 71$) and Dental Hygiene programmes ($n = 25$).

	Primary Dental Degree Programme			Dental Hygiene Programme		
	Count (*n*)	%	Mean, median amounts	Count (*n*)	%	Mean, median amounts
No	23	32.4		20	80.0	
Yes for pre-clinical activities	42	59.2	1178, 1000 (SD = 1120)	5	20.0	612, 260 (CD = 611)
Yes for clinical activities	21	29.6	1601, 1500 (SD = 1314)			

Student numbers in DH programmes are most often dictated by a national body (60%) or set locally by the university (40%). DH students are mostly recruited from secondary school (84%), although four schools report alternative pathways (Table 5). The selection of students into DH programmes most often is determined by the universities and/or dental schools themselves (Table 6). For five DH programmes, a national body is involved in student selection; and in another case, selection is performed through a national third level application service.

Several different criteria are used in the selection of students for the PDDPs (Figure 4). Most commonly, previous academic grades (50.7%) and written examinations conducted by the region/country (46.5%) are used. Further, only 10 of the 71 participating schools require some post-high school study prior to enrolment on a PDDP. These requirements vary and some range from a single year of study in health sciences to completion of an undergraduate degree.

Similarly, DH students are selected using a variety of methods (Figure 4). The most common criteria used to select DH students include academic grades (56%) and written examinations (40%). No schools use a practical test. Further, three schools require that students complete some post-secondary school study prior to beginning their DH programme: college level education in nursing or dental assisting, dental assistant qualification or study at a pre-university college that leads to European Qualification Framework (EQF) level 5.

OHP schools use many different strategies to widen participation in PDDP and DH programmes from under-represented groups (Figure 5). Most often, PDDPs use scholarships (66.2%) and to a lesser extent: community engagement (28.2%), reduced entry requirements (23.9%) and introduction to oral healthcare initiatives (21.1%). DH programmes use similar strategies.

TABLE 3 Students accepted into Primary Dental Degree ($n=71$) and Dental Hygiene programmes ($n=25$) each year.

	Primary Dental Degree Programme		Dental Hygiene Programme	
	Count (*n*)	%	Count (*n*)	%
Fewer than 10	1	1.4	3	12.0
11–20	3	4.2	9	36.0
21–40	9	12.7	11	44.0
41–60	10	14.1	1	4.0
61–80	13	18.3	1	4.0
81–100	14	19.7		
101–150	14	19.7		
151–200	5	7.0		
201–250	2	2.8		

TABLE 4 Estimated percentage of female graduates in Primary Dental Degree ($n=71$) and Dental Hygiene programmes ($n=25$).

	Primary Dental Degree Programme		Dental Hygiene Programme	
	Count (*n*)	%	Count (*n*)	%
0–10	2	2.8		
11–20	2	2.8		
21–30	0	0.0	2	8.0
31–40	1	1.4		
41–50	9	12.7		
51–60	16	22.5		
61–70	24	33.8	1	4.0
71–80	12	16.9	6	24.0
81–90	4	5.6	5	20.0
91–100	1	1.4	11	44.0

3.1.6 | Language of study

Thirteen schools (18.3%) offer PDDPs in a different language from the main language of instruction. At least one school in each of the following countries offers instruction in English: Croatia, Hungary, Latvia, Lithuania, Poland, Romania, Spain and Turkey; while one school in Hungary also offers instruction in German, and a school in Spain offers Catalan.

3.1.7 | Permission to practice after graduation

Upon graduation from PDDPs, 54 schools (76.1%) report that their students are permitted to practice immediately (Table 7). For five schools, permission depends on which health system the student is wanting to work in. Two schools stated that their students need to complete 1 year of vocational training. Ten schools stated that their

TABLE 5 Most common source of recruitment of students in Primary Dental Degree ($n=71$) and Dental Hygiene programmes ($n=25$).

	Primary Dental Degree Programme		Dental Hygiene Programme	
	Count (*n*)	%	Count (*n*)	%
High school	54	76.1	21	84.0
University level pre-dental programme	14	19.7	0	0
Other	3[a]	4.2	4[b]	16.0

[a]Of the Other responses for PDDP: 1 respondent = Colleges that provide EQF Lev 5; 1 respondent = DH and prosthesis, vocational training; 1 respondent = majority are recruited after compulsory military service following secondary school.

[b]Of the Other responses for DH: 1 respondent = Mix of school leavers and professionals; 1 respondent = Nurses, dental assistants; 1 respondent = Pre-University College that leads to EQF Level 5; 1 respondent = must have EQF Level 4, although many work as dental assistants prior to studying dental hygiene.

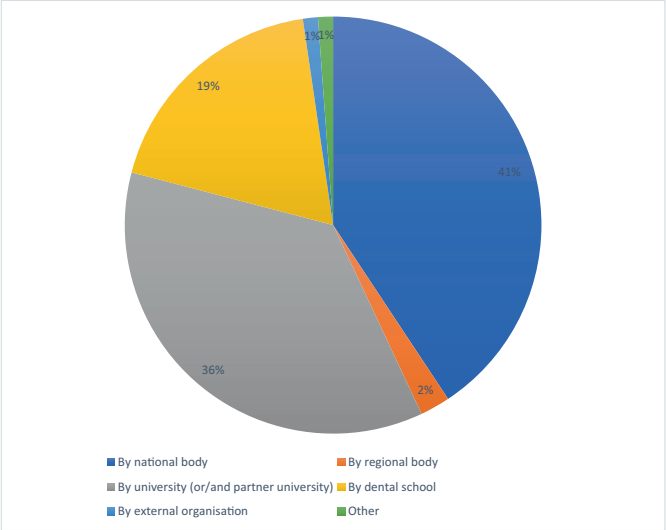


FIGURE 3 Student selecting bodies on Primary Dental Degree Programmes. Of the Other responses: 1 respondent = CAO (Irish Central Applications Office); 1 respondent = TMS (Test for Medical Studies).

TABLE 6 Selection of students in Dental Hygiene programmes ($n = 25$).

N = 25	Count	%
By national body	5	20
By regional body	0	0
By university (or/and partner university)	12	48
By dental school	12	48
By external organisation	0	0
Other	1	4

Note: Of the Other responses: 1 respondent = CAO (Irish Central Applications Office).

students must pass a state examination to practice. One school stated that further formal study is required.

Upon completion of their DH programmes, graduates from 24 of the 25 schools who participated are permitted to practice immediately (Table 7), although at least one school report that graduates must complete one year of post-graduate vocation training.

3.2 | Postgraduate degree programmes

3.2.1 | Language of study

Postgraduate dental programmes are delivered in 16 different languages by the 64 schools that provided information about their post-graduate programmes. Sixteen schools offer programmes in a language other than the primary language of instruction. In Italy, five schools offer instruction in English as well as in Italian. In Spain, two schools offer instruction in English in addition to Spanish, and one school whose primary language is English offers alternative instruction in Spanish. One school in each of the following countries offers alternative instruction in English: Croatia, Greece, Sweden, Hungary, Lithuania, Poland, Portugal and Romania.

3.2.2 | Programme fees

The home fees associated with post-graduate non-clinical years or programmes most commonly are between €2001 and €5000 per year (21.9%) (Figure 2). That said, 28 of the 64 schools selected the 'Not applicable' response option. For clinical years, only 10 schools selected the Not applicable response option; and 53.2% of schools report their tuition fees to be less than €10001 per year. The upper range of fees is €25001–€50000.

The most common range for international fees associated with post-graduate non-clinical years is also between €2001 and €5000 (14.1%) (Figure 2). However, more schools request fees greater than €20000 for international fees compared to home students. The most common range for postgraduate clinical years is higher between €5001 and €10000 (15.6%); but 40% of schools reported higher tuition fees than this range.

3.2.3 | Postgraduate study programmes

A variety of levels of post-graduate programmes are offered (Table 8). Fifty-six of the 64 schools offer PhD research programmes (87.5%) and the next most common programmes are Masters (65.6%)

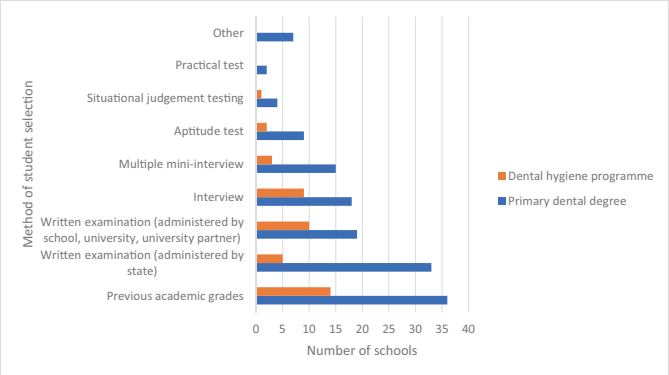


FIGURE 4 Number of schools using these methods of student selection in Primary Dental Degree and Dental Hygiene programmes. Of the Other responses: 1 respondent = ?; 1 respondent = A-level (Abitur), test for medical studies (TMS), years in PQE (Berufserfahrung), apprenticeship in medical field; 1 respondent = Academic test; 1 respondent = Information provided in application forms; 1 respondent = National University Entrance Exam; 1 respondent = personal portfolio; 1 respondent = Written and oral examination; 1 respondent = Written examination administered by our regional body.

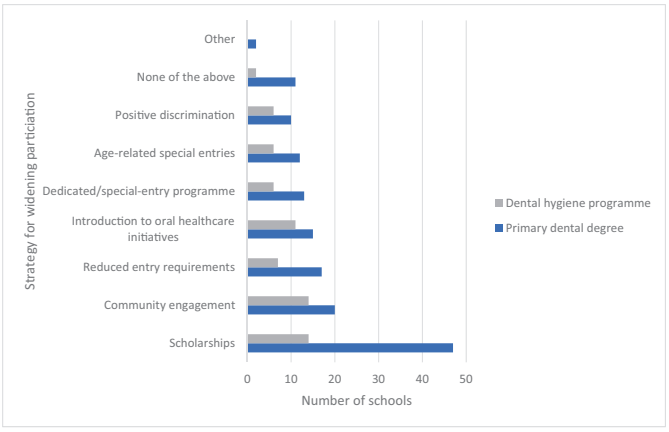


FIGURE 5 Strategies for widening participation of under-represented groups in Primary Dental Degree and Dental Hygiene programmes. Of the Other responses: 1 respondent = Places are reserved for people wishing to make a professional reconversion and who already have a university education; 1 respondent = University provides a pre-dental year foundation programme.

TABLE 7 Permission to practice as a dentist ($n = 71$) or dental hygienist ($n = 25$) immediately after graduation from respective programmes.

	Primary Dental Degree Programme		Dental Hygiene Programme	
	Count (*n*)	Percent (%)	Count (*n*)	Percent (%)
Depends in which health system they want to work	5	7		
No	12	16.9	1	4
Yes	54	76.1	24	96

Note: 1 respondent for a DH programme reported that one year of post-graduate vocational training is required.

and postgraduate diplomas (59.4%). Further, schools offer a wide variety of programmes across the disciplines of dentistry (Table 9). The two most common postgraduate programmes offered and associated with specialist status are Orthodontics and Oral Surgery, while the four most common not associated with specialist status are Implantology, Endodontics, Periodontics and Prosthodontics.

4 | DISCUSSION

This study achieved the aim of presenting data regarding OHP education from institutions representing a variety of geographical locations across Europe. Further data regarding curriculum structure, facilities, staffing (faculty) and quality assurance are presented in Part 2 of this series.

4.1 | Primary Dental Degree Programme and Dental Hygiene

Institutions from 25 European countries, including 20 European Union member states, provided data for their respective programmes. Within these countries there were no submissions for DH programmes in Belgium, Croatia, Cyprus, France, Georgia, Germany, Greece, Netherlands, Poland, Spain, Sweden and Turkey. DH regulation varies across Europe and some countries do not recognise the profession (e.g. France). The profession of DH has been increasingly adopted across European countries since the early 2000s with the European Federation of Periodontology and the European Dental Hygienists Federation stating that 26 EU/EEA countries recognised DH in 2018.[13,31] Adding further complexity, DH forms a group of wider professions in some countries – termed dental hygiene and dental therapy. In the UK, dental hygiene and dental therapy are separate professions with different scopes of practice, with many programmes offering dual qualification.[13,32] The terminology and scope of practice of these professionals vary on a country-by-country basis. These diverse terms are replicated across OHP programmes and therefore presence or absence of data submissions may be related to the challenges in understanding and terminology.

TABLE 8 Levels of postgraduate OHP programmes offered ($n = 64$).

	Count	%
Postgraduate diploma	38	59.4
Masters	42	65.6
PhD	56	87.5
Clinical doctorate	15	23.4
Doctor of Education (EdD)	1	1.6

4.1.1 | Programme length

The EU directive 2005/36/EC, and the amendment 2013/55/EU, state that PDDPs must have a minimum duration of 5 years and 5000 hours full-time theoretical and practical training.[3,5] In this dataset, most schools deliver 5-year programmes with less than a quarter of schools delivering 6-year programmes. Programme lengths tend to cluster by country in response to national regulations. According to the CED's Manual of Dental Practice, 10 EU/EEA countries deliver their PDDPs over more than 5 years and countries within this dataset include Croatia, Estonia, France, Germany, Netherlands and Romania.[8] The data presented within the CED's Manual of Dental Practice aligns with some of our findings, although there are some inconsistencies across countries. Within our dataset it can be noted that some respondents from the same country provided different information for PDDP duration. This may be an accurate representation of variation within countries or there

TABLE 9 Postgraduate programmes offered ($n = 64$).

	Not offering this programme (n)	Available but not associated with specialist status (n)	Available and associated with specialist status (n)
Orthodontics	8	12	43
Oral surgery	11	15	36
Periodontics	13	25	21
Implantology	15	30	7
Endodontics	16	26	21
Paediatric dentistry	16	19	27
Prosthodontics	16	25	20
Restorative dentistry	22	22	11
Aesthetic dentistry	25	21	6
Oral medicine	27	14	10
Oral pathology	29	16	5
Occlusion/TMD	29	15	5
General clinical dentistry	30	12	9
Special care dentistry	30	11	7
Radiology (dental and maxillofacial)	33	8	10
Dental Public Health	37	8	4
Oral microbiology	43	1	3

may be confusion between programme length and the expected length of study. Attempts were made by the research team to avoid this confusion by providing links in the questionnaire to the exact definitions within the Articulate glossary.[2] Some countries require prospective dental students to undertake a basic science or foundation year, and this may be perceived as a component of dental programmes. Additionally, some respondents provided details of 4-year graduate-entry programmes and in essence these are 5-year programmes with approved prior learning from previous terms of study. The length of study for DH is also variable and will likely reflect the differences in the scope of practice across countries – with a more limited scope of practice potentially requiring shorter periods of study. Three-year Bachelor length programmes are the most common within this dataset.

4.1.2 | Programme funding

The percentage of schools that are privately funded within this dataset is similar to the CECDO database and the CED Manual of Dental Practice that estimated 14% and 9%, respectively.[7,8] Importantly, these results reflect the opinions of staff who feel their institution is funded in this way. There may be differences in interpretation of the question as some institutions are predominantly funded by the state and this funding enables them to deliver their core programmes; however, these same institutions may have commercial agreements with other stakeholders or receive funding through donations.

4.1.3 | Programme fees

It is interesting that a high number of schools (between 14 and 18) selected the 'not applicable' option with regard to home and international fees for both PDDP and DH programmes. The reasons for this may be that participants do not offer the programme, could not answer the question or did not want to share this information. By way of an example: in Ireland tuition is free for most EU students, although there is a "student contribution" of a maximum of €3000 – thereby making completion of this question challenging.[33] It is evident that fees vary significantly across Europe for OHP programmes, but it is positive that 50% (PDDPs) and 60% (DH) of respondent schools reported tuition fees of less than €5001. International fees are commonly higher than home fees across all programmes. It appears from the data that very few schools charge extra tuition fees for the clinical years of PDDP or DH. However, many institutions ask students to pay additional fees for pre-clinical and clinical activities. These fees present a substantial additional cost to students and financial support is not available in many contexts. Considering the high fees associated with OHP programmes and limited uptake of widening participation strategies in some contexts, existing inequalities in the profession may remain.

4.1.4 | Student numbers

Across Europe, OHP student numbers are predominantly determined by national or regional bodies (e.g. regulators, governmental departments), with a smaller proportion determined locally by the university or school. Regardless of who determines the student admission numbers, programmes should be aligned with future visions for the workforce to avoid inequity in the distribution of OHPs and resultant services across the continent. Student admission numbers were reported between 61 and 150 students per year across most PDDPs. It is of note that one school admits fewer than 10 students and two schools admit more than 200 students per year. It would be of interest for future work to note how programme structure, curricula, facilities and staffing differs in institutions with such vast disparities in admission numbers. There is less variance in DH, with generally smaller student cohorts. The difference in students admission numbers between PDDPs and DH is of interest and is likely to change in the future in light of the recent WHO Global Strategy on Oral Health.[1] This report recommends changes to the OHP workforce by increasing 'mid-level oral health care providers' to respond to population oral health needs.[1] Due to the evolving nature of the data hub, institutions can change the data they have provided, which will enable stakeholders to follow changes in OHP workforce numbers.

4.1.5 | Student demographics

With regard to gender distribution of students on dental and DH programmes, there appears to be a higher reported proportion of females on both programmes. There are exceptions within both programmes and trends across Europe will replicate cultural differences across the European continent. This data aligns with the CED Manual of Dental Practice and the CECDO database that estimate the number of female graduates from PDDPs to be between 60% and 70%.[7,8] In the early 2000's it was estimated that 96.5% of European dental hygienists were female.[34] Our data suggests that most graduates of DH in Europe will continue to be female; however, male numbers may be increasing compared to previous estimates. Two recent narratives uncovered existing inequalities in the oral health workforce that have persisted irrespective of the increase in female OHPs, particularly across different ethnic groups.[35,36]

4.1.6 | Student admission and selection

Most students reportedly enter their PDDP and DH programmes directly from high-school and this differs to models in other regions of the world such as North America.[37] Almost 20% of schools delivering PDDPs recruit primarily from university level pre-dental programmes. These may include foundation or basic science years, or graduate entry programmes whereby students must demonstrate

approved prior learning through the completion of a university level degree. DH follows a similar trend – most institutions recruit students directly from high-school. Sixteen percent of respondent DH schools selected 'other' which included recruiting qualified OHP professionals (nurses/assistants, technicians) and other post-high school study. It is acknowledged that recruitment regulations are often managed by universities for DH and the level of programme (EQF level 5 or 6) will impact on the entrance requirements and therefore the nature of the cohort admitted. There is a risk of excluding valuable members of the current OHP workforce if entrance requirements are too restrictive.

The management of student selection is variable across Europe for PDDPs with an interesting observation that most European OHP schools do not select their own students. The data is different for DH where universities and dental schools predominantly control the student selection process. Methods of student selection for both programmes appear similar, with previous academic grades, written examinations and interviews being the most reported. Other means of student selection including situational judgement aptitude tests were administered by less than 10 OHP schools. It is of interest that a very low number of schools ($n = 2$) include practical tests in their selection processes considering the practical nature of the profession.

There is limited evidence and few recommendations on student selection processes in the dental education literature. A report by a group of international educators that stemmed from the DentEdEvolves Thematic Network Project considered best practices in student selection including aptitude tests, written examinations, and interviews.[38] According to our data, these practices appear to be adopted for the most part across Europe – although these recommendations are now more than 20 years old. Additionally, a factor analysis study in the UK utilising a multiple mini-interview approach to student selection demonstrated the importance of assessing both 'soft' skills (e.g. communication, empathy) and sensorimotor abilities.[39] Due to the popularity of OHP programmes and resultant applicant numbers, bodies that govern student selection will inevitably need to find a balance between idealism and feasibility.

With regard to strategies of widening participation of underrepresented groups in higher education, scholarships are most common within this dataset. Scholarships largely refer to support measures to overcome financial barriers that may impact one's ability to enrol on an OHP course. These approaches are important as financial reasons are perceived as a significant barrier by prospective OHP students from underrepresented groups.[40,41] However, financial concerns are not the only barrier – limited exposure to the oral health professions, a lack of community support and role models are also significant issues. Methods to confront these barriers that focus on education and opportunities (community engagement, reduced entry requirements and introduction to oral healthcare initiatives) appear less common. More than 10 OHP schools either do not offer widening participation strategies or do not undertake any of the methods outlined in the questionnaire.

4.1.7 | Language of study

Most OHP schools offer programmes in a single language, most commonly the national language of the country. However, there is a significant proportion of schools that offer programmes in multiple languages which may help in attracting international students and provides opportunities for institutions to grow. Some institutions within countries that have a second national (or regional) language may offer students opportunities to sit certain components of their programme in another language, although many do not deliver a whole programme in these languages. Additionally, some institutions deliver theoretical components in multiple languages but often conduct clinical education in the national language to support communication with the local patient population.

4.1.8 | Permission to practice after graduation

Approximately 78% of schools reported their graduating dentists can practice immediately after graduation from their respective programmes. The remaining schools reported that either state examinations or a period of vocational training must be completed prior to commencing independent practice as a qualified professional. According to the CED's Manual of Dental Practice, graduates from Belgium, Croatia and Slovenia must complete 1 year of vocational training regardless of the healthcare system, whilst graduates from Germany, Switzerland and the United Kingdom must complete 1 year of vocational training to work in the National Health Service.[8]

4.2 | Postgraduate programmes

It was not within the scope of the data collection to focus on the finer details of postgraduate programmes across Europe. It can be acknowledged that many institutions across Europe offer postgraduate programmes in languages different from the national language and this is predominantly English. As for PDDPs, this likely stems from a desire to increase international student numbers and associated benefits to the institution.

Postgraduate tuition fees vary across Europe with a general sense that postgraduate fees are higher than those for undergraduate programmes. In comparison to undergraduate programmes (PDDP and DH), postgraduate fees are generally more expensive, with greater saturation from the more than €15 000 per year options. This is likely to result from greater costs in hiring staff to deliver these courses and additional equipment that may be required.

OHP schools across Europe offer a wide range of postgraduate programmes across numerous levels – from postgraduate diplomas to research, clinical and education doctorates. Only one school within the dataset did not offer postgraduate programmes at the time of submission. It appears that institutions do not prioritise postgraduate research programmes in education with only one school offering a Doctor of Education (EdD) programme.

It can be concluded from the dataset that OHP institutions are also offering a wide range of programmes, with 551 programmes offered from the discipline list in the questionnaire, making a mean of 8.6 postgraduate programmes per OHP institution ($n = 64$). The number, definition and acceptance of individual disciplines within dentistry vary hugely across Europe.[42] In the EU, the most recent directive only recognises two specialties: Oral Surgery and Orthodontics.[3] However, this document only recognises formal qualifications that lead to speciality recognition within member countries, it does not regulate the education or acceptance of specialties – this is managed by individual countries. This has led to wide disparity with some countries recognising no specialties (e.g. Spain) and others recognising many (e.g. United Kingdom – 13 specialties). It is also likely, due to this variance, that understanding of the terminology will lead to confusion, with some countries heavily regulating the specialist title whilst others adopt the title "specialist" after completing any form of postgraduate study. According to the EU directive 2013/55/EU, postgraduate programmes that lead to specialty status must be a minimum of three years duration and approved by competent authorities or bodies in each country.[5]

As expected, the two EU-recognised specialties of Oral Surgery and Orthodontics are the most prevalent programmes across Europe, with Periodontics, Endodontics, Prosthodontics and Paediatric Dentistry also very popular. To further add to the confusion, specialty training is delivered by hospitals in some countries rather than universities and this may have also impacted responses. Due to the large disparities in regulation of specialities across Europe it is impossible to analyse the dataset further.

4.3 | Limitations of the research

This was an ambitious project that aimed to establish a viewpoint on the current state of OHP education in Europe and in many respects, this has been achieved. As the data hub remains live, this series of papers will hopefully provide a foundation, with the hope of gaining more data in the future. There are some limitations within this dataset that should be highlighted. It is challenging to generalise the findings of this research to OHP education across the whole of Europe. The reasons for this are: (i) the exact number of OHP schools across Europe is not known, (ii) the dataset does not cover all regions of Europe. It is not the aim of this manuscript to provide generalisable statements on European OHP education, but rather it is to provide insight into existing structures from a large group of institutions across many European countries and to draw comparisons of different practices and approaches.

It is feasible that there could be an element of sampling bias within this survey as ADEE member OHP schools were invited to provide data. The researchers were aware of this from the outset of the project, and it was impossible to resolve due to challenges in communicating and finding non-ADEE members in Europe. Additionally, it could be hypothesised that ADEE members schools are more engaged in educational processes and perhaps are quicker to adopt new practices, again which impacts the generalisability of this data. As with any data from surveys there is risk of response bias whereby respondents provide inaccurate data that adopt to perceived standards or desirable options.

A final consideration is the questionnaire being written in English exclusively. This was intentional as translation of the consensus-agreed terminology from the Articulate glossary would likely have resulted in unidentifiable changes in meaning which would have impacted the accuracy of the responses. It is acknowledged that using English for a survey that spans a continent of multiple languages may have provided challenges in answering some questions and misunderstandings may be present in the data. As the project team members are based in a large area of the European continent and speak multiple languages, attempts were made to limit this by offering support when needed.

5 | CONCLUSION

This series of papers, as far as the authors are aware, are the first attempts to build a comprehensive picture of the current state of OHP education in Europe. This education is unique – with multiple different interpretations and contexts demonstrated in this dataset. Within this paper, important trends and variances have been identified for Primary Dental Degree, Dental Hygiene and Postgraduate programmes across Europe. Most importantly, questions have been raised to support key changes to OHP education in the future.

A comprehensive view of the state of OHP education in Europe is not yet *available* but the O-Health-Edu data hub provides a means for all education providers in Europe to contribute data to reach this goal. In the future, as the O-Health-Edu project *concludes*, ADEE will oversee the functionality and branding of the data hub. It is anticipated that the data hub will be updated and *built* upon over time to continually establish a clearer picture of the state of OHP education in Europe. This is call for collaboration across all institutions and education stakeholders to develop OHP education for the future.

ACKNOWLEDGEMENTS

The authors would like to thank Miguel Braga for the development of the datahub and Judith O'Brien for inviting ADEE member schools to complete the survey. Both also provided technical support to respondents when completing the questions. Their contributions are greatly appreciated.

CONFLICT OF INTEREST STATEMENT

No conflict of interest has been declared by the authors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Dixon J, Field J, Vital S, et al. O-HEALTH-EDU: A viewpoint into the current state of Oral Health Professional education in Europe: Part 1: Programme-level data. *Eur J Dent Educ*. 2024;28:591-606. doi:10.1111/eje.12989

A Viewpoint into the Current State of Oral Health Professional Education in Europe: Part 2: Curriculum Structure, Facilities, Staffing and Quality Assurance.

Aims and Objectives

This series of publications aims (i) to present data regarding OHP education from institutions representing various geographical locations across Europe and (ii) to establish commonalities and trends. Specific objectives for part 2 of this series are to:

- provide a review of core practices in curriculum structure, availability and access to facilities, staffing (faculty) and quality assurance procedures, and
- consider how the current curriculum structures relate to stakeholder guidance documents.

Methodology

This paper includes twenty-seven questions from the 91-item questionnaire. The methodology is identical to that described in Part 1.

Results

Seventy-one institutions from 25 European countries provided curriculum structure, facilities, staffing and quality assurance data. Most schools (42.3%) have a mix of integrated and discipline-based curricula, whilst 38% have a completely discipline-based approach. Most schools (91.5%) across Europe report using national curriculum frameworks. Professionalism (76.1%), critical thinking (73.2%) and evidence-based practice (71.8%) are longitudinally integrated in most schools. Most schools do not teach social accountability (24%) and environmental sustainability (32.4%). Observation of clinical care typically begins in the first three years of dental programmes, although variations exist. In most schools, operative care delivery commences in years 3-5 (87%).

Senior full-time and junior part-time staff appear to form a significant part of the workforce, which raises questions regarding sustainability and succession planning.

Relevance

This study provides key information regarding curriculum structure, facilities, staffing, and quality assurance from a large group of European OHP schools. The data provided should ensure that future curriculum documents are relevant to the real-world situation. Understanding existing curriculum structures, clinical contact, and staffing gives insight into the variability of practices across Europe in relation to a minimally descriptive EU directive. This data and learning derived from this study will directly inform the future work in this thesis by establishing a situational analysis in which curriculum development initiatives will occur. Additionally, the applicability of future recommendations and guidelines will be improved due to this new contextual understanding.

Received: 8 August 2023 | Revised: 18 October 2023 | Accepted: 18 December 2023

DOI: 10.1111/eje.12987

ORIGINAL ARTICLE

WILEY

O-Health-Edu: A viewpoint into the current state of oral health professional education in Europe: Part 2: Curriculum structure, facilities, staffing and quality assurance

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Abstract

Introduction: Oral health professional (OHP) education is likely to vary across Europe in accordance with an EU directive that is open to broad interpretation. It is not clear how OHP curricula are structured or delivered across Europe. The objectives of Part 2 of this paper series are: (i) to provide an overview of common practices in curriculum structure, the availability of facilities, staffing (faculty) and quality assurance processes and (ii) to consider how the existing programme structures align to stakeholder guidance documents.

Methods: A total of 27 questions from a 91-item questionnaire were used for this manuscript. The questionnaire was developed following the Delphi method to establish consensus from a group of experts. Members of the research team and colleagues from other countries in Europe completed a multi-step piloting process. An online data hub was created to allow the respondents to be data controllers and respond to the questionnaire. ADEE member schools ($n = 144$) were invited to provide data.

Results: Totally, 71 institutions from 25 European countries provided data between June 2021 and April 2023, which represents a response rate of 49.3% of ADEE members. Data on curriculum approaches, teaching methods, integration of topics of interest, clinical education, staff–student ratios, access to facilities and new technologies, teaching staff (faculty) and quality assurance processes are presented for Primary Dental Degree Programmes.

Conclusion: To the best of our knowledge, this series of papers are the first attempts to provide a comprehensive overview of OHP education in Europe. Results showed that the majority of European dental programmes are engaged in providing innovative and scientifically grounded education in order to develop quality future OHPs. Nevertheless, significant variability in the delivery of clinical education across the European OHP schools was notable in this dataset. A comprehensive view of the state

of OHP education in Europe is not yet *available* but the O-Health-Edu data hub provides a means for all education providers in Europe to contribute data to reach this goal. It is anticipated that the data hub will be updated and *built* upon over time to continually establish a clearer picture of the state of OHP education in Europe.

KEYWORDS
dental education, dental hygienists, Europe, oral health professionals, survey

1 | INTRODUCTION

The education of oral health professionals (OHPs) is of fundamental importance to deliver equitable and quality oral healthcare in the future.[1] Education providers are strategically positioned to ensure their graduates have knowledge, skills and attitudes that are appropriate to manage the current and future oral health needs of the European population.

The need for data on educational practices in European OHP programmes has been established [2] and gave rise to the O-Health-Edu project.[3,4] While the O-Health-Edu project encompasses all OHP education, this paper will consider curriculum structure for Primary Dental Degree Programmes (PDDPs) and the facilities, staffing and quality assurance measures employed by dental schools.

The curriculum is a challenging construct to define, with research demonstrating a lack of concordance amongst educators in defining the term.[5–9] It has multiple meanings and can be considered in different lights – from a student (receiver) or from educator or institutional (deliverer) perspectives.[10–12] The most expansive definition of the curriculum includes *all* processes that contribute to student learning on a programme of study, these processes may be planned, unplanned or hidden to educators.[7,10] In Articulate, a glossary of OHP education terms, curriculum is defined as: 'detail of a particular course of study, including learning outcomes, the students' expected educational experiences, assessments, and formats for learning'.[3] European regulatory and guidance documents tend to focus on the formally delivered curriculum which typically includes study modules, learning outcomes, competences and learning, teaching and assessment methods.

The Annex V3/5.3.1 of the Directive 2005/36/EC provides details of a study programme for dental practitioners and encompasses basic subjects, medico-biological subjects/general medical subjects and subjects directly related to dentistry within the European Union.[13] Aside from defining the minimum programme length, these are the only regulations to support dental schools in developing their curricula.[13,14] The limited regulations at a European-level leave dental education open to interpretation and significant variability unless national competent authorities or regulators provide additional standards.[2] Examples of such practices are the standards imposed by the 'Ministère de l'enseignement supérieur et de la recherche' in France (2013) and the General Dental Council in the United Kingdom (2015), who defined learning outcomes and standards for education providers.[15–17]

At a European level, the Association for Dental Education in Europe (ADEE) has been a key stakeholder in advancing OHP education for over 20 years. Concerns regarding the variability of dental education stemmed from the findings of Shanley et al. in 1997.[18] The ADEE were subsequently involved in the DentEd Thematic Network Projects and commissioned taskforces to engage in pan-European consultation to formulate the outputs:

- Profile and Competences for the European Dentist.[19]
- Curriculum structure and the European Credit Transfer System for European dental schools: part I.[20]
- Curriculum content, structure and European Credit Transfer System for European dental schools. Part II: methods of learning and teaching, assessment procedures and performance criteria.[21]
- Quality assurance and benchmarking: an approach for European dental schools.[22]

These documents were the first attempts to promote the convergence of European dental education and the profile and competences and curriculum content, structure, learning and assessment documents were further updated in the early 2010s.[23,24]

A significant change to the structure of these documents occurred through development of the Graduating European Dentist (GED) in 2017.[25] This suite of documents replaced the previous profile and competences and curriculum content by incorporating the widely recommended learning outcomes approach to curriculum development. The GED currently has four domains and includes contemporaneous recommendations for learning, teaching and assessment.[26–30] All of these documents are now available online (https://adee.org/graduating-european-dentist) and are open for development with a dedicated taskforce to manage this process on a regular basis.

The GED provides a framework to support schools in developing their curricula within their own contexts. Increasingly, discipline-specific curriculum frameworks are being published in line with recommendations from the GED and the O-Health-Edu scoping review.[2,25] Some of these are outputs of ADEE Special Interest Groups including pre-clinical operative skills and environmental sustainability.[31–34] Others recent examples of discipline-specific curricula are the European Core Curriculum in Cariology and the European Federation of Periodontology documents.[35,36]

As an integral part of quality assurance procedures, changes to dental curricula are driven by numerous factors, including new

developments in the profession, emerging technology and education rationale.[37–40] With contemporaneous recommendations for learning, teaching and assessment and the emergence of new technology in OHP education, such as virtual reality (VR) simulation, an overview of the uptake of these practices is necessary. There are currently no readily identifiable sources to provide insight into educational practice across European dental schools.[2]

The aim of this two-article series is to present data regarding OHP education from institutions representing a variety of geographical locations across Europe and to establish commonalities and trends. Specific objectives for this paper are to:

- provide an overview of common practices in curriculum structure, the availability of facilities, staffing (faculty) and quality assurance procedures, and
- consider how the existing programme structures align to stakeholder guidance documents.

2 | METHODS

This study received approval from the Ethics Committee of the Universitat de Barcelona (IRB00003099, 5th October 2020). Further details regarding the complete questionnaire including instrument development, piloting and recruitment can be found in Part 1 of this series.

A total of 27 questions from the 91-item questionnaire are included in this manuscript, as these referred to curriculum approaches and frameworks (3), teaching methods and integration of topics of interest (2), student opportunities (5), clinical activities, staff–student rations and frequency of clinical sessions (4), access to outreach practice and anatomical dissection (4), access and location of facilities and technology (2), teaching staff/faculty (3) and quality assurance (4). All questions were written in English, no translations were made available. The questions used in this manuscript are available in the Appendix S1.

The development of these questions followed the Delphi method with successive rounds of discussions until consensus was achieved. The content was shaped by the scoping review and previous curriculum documents as well as topics of interest raised at ADEE meetings.[2,25–31,33,34] The Articulate glossary was written concurrently with the questionnaire and all key words within each question were defined.[3] These terms were then linked to the questionnaire to establish a common understanding and to facilitate completion.

The questionnaire was piloted in multiple stages with members of the O-Health-Edu project, an external quality committee and a group of European OHP academics. Modifications were made to improve quality and clarity. An additional consultation was performed with OHP stakeholders including the CED (Council of European Dentists), the FEDCAR (Federation of Regulatory Authorities), the EDSA (European Dental Student Association) and the ADEA (American Association of Dental Education). To develop a live and updatable datahub, the questionnaire was uploaded onto the O-Health-Edu website (https://o-health-edu.org/ohe-datahub-directory). The datahub allows responding schools to create an account and respond to the questions in the questionnaire. This approach allows individual OHP schools to control, access and modify their data at any time.

All OHP schools in Europe were eligible to provide data for their institution but due to challenges in identification and communication, only ADEE registered schools ($n = 144$) were directly invited to register on the O-Health-Edu website. Institutional contacts (either the Head of School/Dean or their designated contact) provided data for their institution. Technical and academic support was available to help institutions in submitting their data. The data reported in this manuscript was collected until the 17th April 2023, although the data hub continues indefinitely with institutions welcome to submit data. Any data provided from institutions outside of the 53 European countries set out in the WHO definition of Europe were excluded.

The data were analysed using descriptive statistics. The IBM SPSS Statistics program (version 26) was used to present the data in counts and percentages. The results were presented in tables, graphs and charts using Microsoft Excel 2017. Due to the small and non-representative sample of the many schools throughout Europe, few comparisons between groups of schools were made. One question had a free-text answer – 'List the type of processes that are included in your internal quality assurance process'. Content analysis was used to establish frequency of responses for this question.

3 | RESULTS

A total of 71 schools from 25 European countries provided data between 8th June 2021 and 17th April 2023. Within these schools, 25 offer dental hygiene programmes. Programme-level data for PDDPs, dental hygiene and postgraduate education as well as the demographics of this dataset can be found in Part 1 of this series. All of the data included within this manuscript relate to PDDPs. In the Articulate Glossary, this is defined as: 'A course of study resulting in qualification as a dentist'.[3]

3.1 | Curriculum approaches and frameworks

Curricula across the 71 dental schools that contributed data are varied with 14 schools (19.7%) using a completely integrated approach, and 27 schools (38%) using a discipline-based approach. The majority of schools ($n = 30$, 42.3%) report that both approaches co-exist in their curricula. The sources used to guide PDDP curricula are varied and most schools ($n = 65$, 91.5%) rely on a national framework (Table 1). Two schools from Spain and one

	Count (*n*)	Per cent (%)
International framework (Graduating European Dentist)	42	59.2
National framework	65	91.5
Discipline-specific	23	32.4
Own curricula developed within school	44	62.0
Curricula developed by other dental school(s)	12	16.9

TABLE 1 Sources used to guide curricula for Primary Dental Degree programmes ($n = 71$).

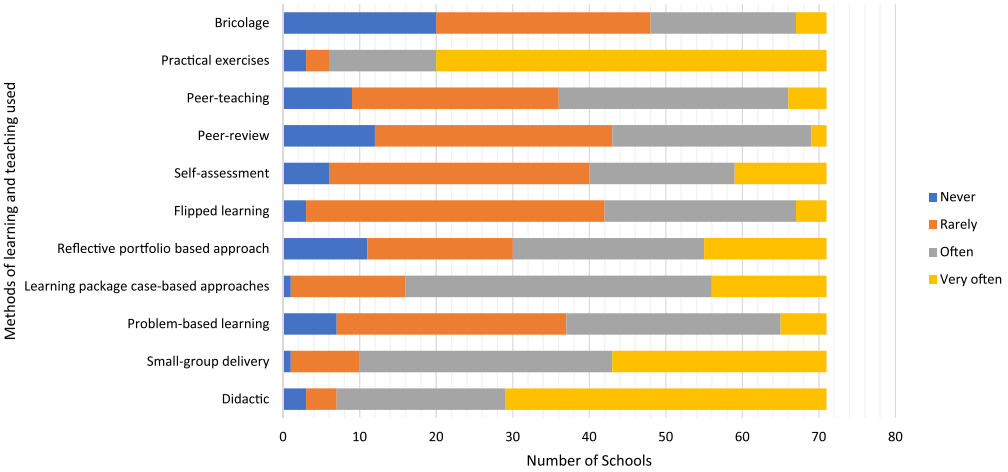

FIGURE 1 Methods of learning and teaching used within the Primary Dental Degree Programmes ($n = 71$).

each from Malta, Cyprus, Denmark and Israel did not report the use of a national framework. Sixty-two per cent of schools develop their own curricula and 59.2% utilise an international framework – the Graduating European Dentist.[25] From the free-text responses for discipline-specific curricula, the European core curriculum in cariology,[35] the European Federation of Periodontology curriculum guidelines[36] and ADEE's pre-clinical operative skills curriculum[34] were popular resources.

3.2 | Teaching methods and the integration of topics of interest

The most frequent methods of learning and teaching used within PDDPs are practical exercises (Very often; $n = 51$, 71.8%) and didactic delivery (Very often $n = 42$, 59.2%) (Figure 1). The least used methods are bricolage (Never; $n = 20$, 28.2%) and peer-review (Never; $n = 12$, 16.9%). Many schools report that critical thinking ($n = 52$, 73.2%), professionalism ($n = 54$, 76.1%), and evidence-based practice ($n = 51$, 71.8%) are longitudinally integrated into their curriculum, while social accountability ($n = 17$, 24%) and environmental sustainability ($n = 23$, 32.4%) are not integrated at all or are in the planning stage of integration (Figure 2).

3.3 | Student opportunities

In terms of student opportunities within and beyond the core curriculum, many schools have a research component (mandatory; $n = 25$, voluntary $n = 44$), opportunities to study abroad for more than 2 months (within EU; $n = 57$, outside of EU; $n = 23$) and opportunities to volunteer and participate in Interprofessional Education (IPE) (Table 2). Sixty-six per cent of schools provide opportunities for IPE, with 45.1% providing specific IPE learning objectives/outcomes and the majority (53.5%) of schools offering opportunities for IPE with *other* health professionals (not OHPs).

3.4 | Clinical activities, staff–student ratios and the frequency of clinical sessions

Clinical observation commonly begins in one of the first 3 years of the PDDP, with the delivery of increasingly complex patient care occurring as students' progress through programmes (Figure 3). However, there are six institutions that commence observation of patient care in Year 4 or 5, with 47.9% of schools permitting students to deliver operative care from Year 4 onwards. Additionally, as students' progress, they commonly have increasing numbers of clinical sessions to

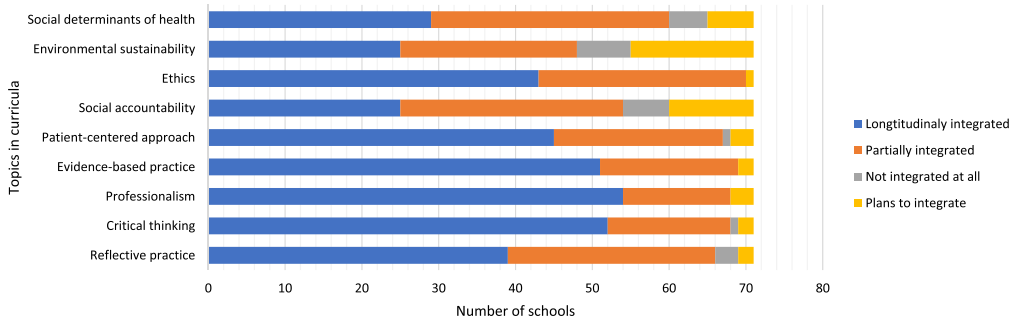

FIGURE 2 Integration of topics of interest within the Primary Dental Degree Programme curricula ($n = 71$).

TABLE 2 Student opportunities as part of their studies in a Primary Dental Degree Programme ($n = 71$).

	Count (*n*)	Per cent (%)
Student opportunities for research as part of studies		
No	2	2.8
Yes, mandatory	25	35.2
Yes, voluntary	44	62.0
Student opportunities for studying abroad (>2 months)		
No	14	19.7
Yes, within Europe	57	80.3
Yes, outside of Europe	23	32.4
Scope of study in another country		
Research	12	16.9
Erasmus (clinical) or equivalent	53	74.6
Erasmus (Pre-clinical) or equivalent	34	47.9
Other	4.0	5.6
Student opportunities to volunteer during their studies		
Yes, organised by the institution	38	53.5
Yes, not organised by the institution	41	57.7
No	8	11.3
Student opportunities to participate in interprofessional education (IPE) as part of their studies		
Yes, with specific educational objectives for IPE	32	45.1
Yes, but without specific IPE objectives	15	21.1
No	24	33.8
Which other professionals do students study and learn with on a regular basis?		
Other OHPs	25	35.2
Other health professions	38	53.5
Professions outside health sector	5	7.0
Other	2	2.8

attend, with similar patterns for 5-year PPDPs (Figure 4A) and 6-year programmes (Figure 4B). Part 1 of this series provides programme level data on all respondents including programme length. One school offered a 4-year graduate entry programme and therefore is not included in Figure 4A,B. The most common staff–student ratio on dental clinics is 1:2–7 ($n = 43$, 60.6%), followed by 1:8–12 ($n = 22$, 31.0%) (Table 3). The most common staff-to-student ratio in clinical skills teaching laboratories is 1:8–12 ($n = 31$, 43.7%).

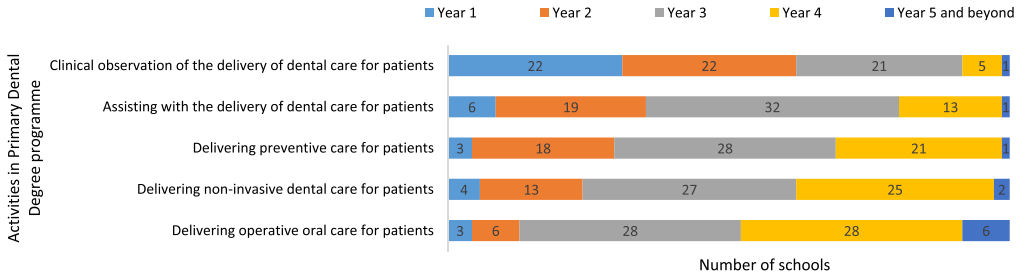

FIGURE 3 Commencement of clinical activities in the Primary Dental Degree Programmes by year ($n = 71$).

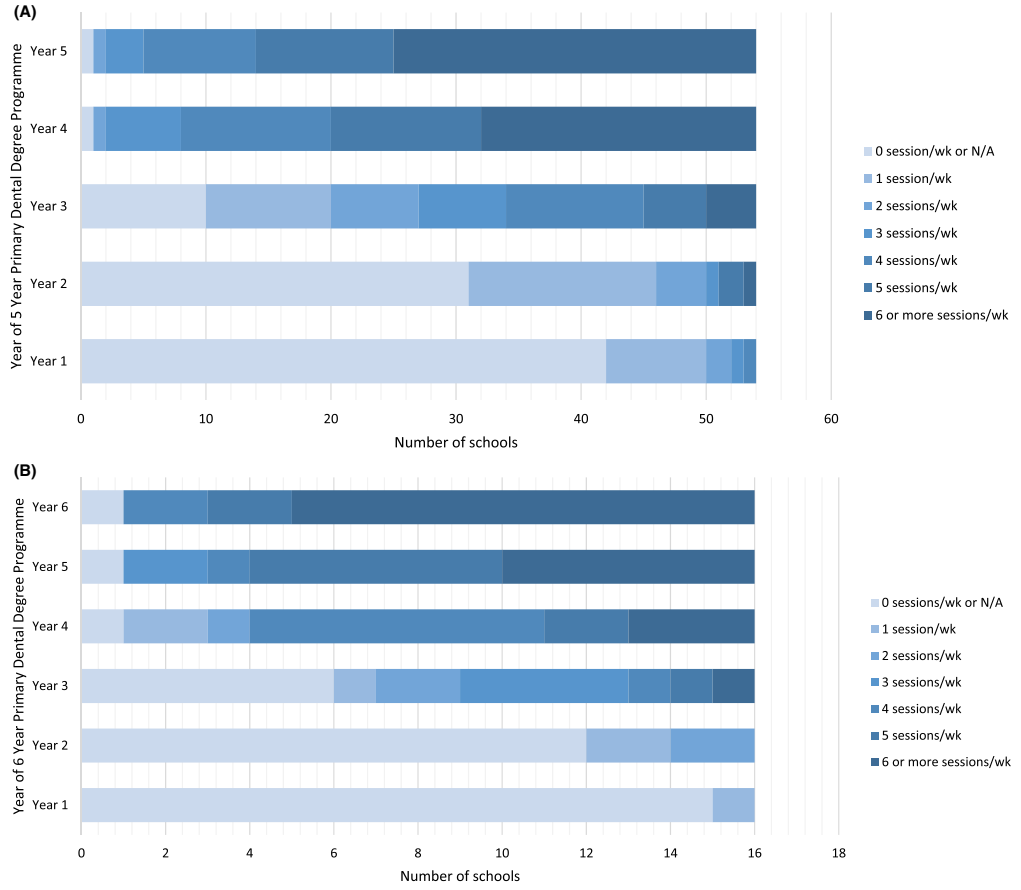

FIGURE 4 Average number of clinical sessions per week that students on (A) 5 year Primary Dental Degree Programme must attend ($n = 54$). (B) 6 year Primary Dental Degree Programme must attend ($n = 16$).

TABLE 3 Typical staff–student ratios in clinical and clinical skills teaching laboratory spaces for Primary Dental Degree Programmes.

Staff–student ratio	Count (*n*)	Per cent (%)	Staff–student ratio	Count (*n*)	Per cent (%)
Clinics			**Clinical Skills Laboratories**		
1:1	1	1.4	1:1–7	12	16.9
1:2–7	43	60.6			
1:8–12	22	31.0	1:8–12	31	43.7
1:13–20	5	7.0	1:13–20	21	29.6
1:20+	0	0.0	1:21–35	7	9.9
			1:35+	0	0.0
Total	71	100.0	Total	71	100.0

TABLE 4 Primary location of learning and teaching facilities and services (*n* = 71).

	In the dental school		Outside the dental school		Not available	
	Count (*n*)	Per cent (%)	Count (*n*)	Per cent (%)	Count (*n*)	Per cent (%)
Dental clinic	64	90.1	7	9.9	0	0.0
Physical library	41	57.7	30	42.3	0	0.0
Research laboratory	56	78.9	13	18.3	2	2.8
Dental VR simulator	33	46.5	2	2.8	36	50.7
Clinical skills teaching laboratory	67	94.4	4	5.6	0	0.0
Technical skills teaching laboratory	68	95.8	3	4.2	0	0.0
Support and well-being services	30	42.3	38	53.5	3	4.2

3.5 | Access to outreach practice and anatomical dissection

Forty-nine of 71 (69.0%) schools offer primary programme dental students the opportunity for outreach practice; while 21 of the 25 schools (84.0%) with dental hygiene programmes do too. Fifty-seven schools (80.3%) provide students with access to dissection on their PDDPs. Most have access to physical dissection (*n* = 26, 45.6%), with 11 schools (19.3%) using virtual dissection and 20 schools (35.1%) employing both techniques.

3.6 | Access and location of facilities and technology

Dental students across Europe are able to access a range of different facilities (Table 4). Most commonly, teaching laboratories (for technical skills; *n* = 68, 95.8%; for clinical skills; *n* = 67, 94.4%) are located within OHP schools. Support and well-being services (*n* = 38, 53.5%) and physical libraries (*n* = 30, 42.3%) are often located outside of the school. Furthermore, almost half of the schools have access to dental VR simulators either inside (*n* = 33, 46.5%) or outside (*n* = 2, 2.8%) the dental school.

Dental students also have access to a number of teaching technologies (Table 5). The most common are digital radiography (*n* = 65, 91.5%), electronic health records (*n* = 56, 78.9%), and e-books (*n* = 54, 76.1%). Some technologies such school-owned portable electronic devices (*n* = 32, 45.1%) and 3D printing (*n* = 11, 15.5%) are less readily available.

3.7 | Teaching staff (faculty)

Returning to the topic of teaching staff, the number of junior and senior part-time and full-time staff is highly variable amongst the schools that provided data (Table 6). On average, junior part-time staff (42.05%) and senior full-time staff (28.06%) form a largest part of the teaching workforce. The mean percentages of junior full-time (15.07%) and senior part-time staff (14.81%) are smaller and similar to each other. Fifty-five schools report that their percentage of female teaching staff ranged between 41 and 70% (Figure 5). Two schools report having 0–10% female teaching staff, while three schools have at least 81%. The qualifications that newly recruited senior teaching staff are required to hold is most often a research qualification such as a PhD or Masters (*n* = 59, 83.1%) (Figure 6).

3.8 | Quality assurance processes

The vast majority of schools (*n* = 63, 88.7%) have a regular process of internal quality assurance that are either school or university-driven. Six schools (8.5%) do not employ internal quality assurance processes and respondents from two schools (2.8%) did not know if these processes were used. Student feedback, course evaluation

TABLE 5 Extent to which teaching technologies are available for use by students ($n = 71$).

	Regularly used		Infrequently used		Not available	
	Count (*n*)	Per cent (%)	Count (*n*)	Per cent (%)	Count (*n*)	Per cent (%)
Lecture capture	52	73.2	16	22.5	3	4.2
Digital radiography	65	91.5	5	7.0	1	1.4
Electronic health records	56	78.9	13	18.3	2	2.8
Intra-oral scanning	36	50.7	29	40.8	6	8.5
3D printing	24	33.8	36	50.7	11	15.5
E-books	54	76.1	13	18.3	4	5.6
School-owned portable electronic devices for students	18	25.4	21	29.6	32	45.1
Operating microscopes	29.0	40.8	33	46.5	9	12.7

TABLE 6 Average composition of teaching staff working within OHP schools.

	Percentage of staff type where count for each type >0		
Type of teaching staff	Mean	SD	Median
Junior full-time	15.07	13.25	10.61
Junior part-time	42.05	18.45	38.22
Senior full-time	28.06	14.02	27.59
Senior part-time	14.81	12.12	12.50

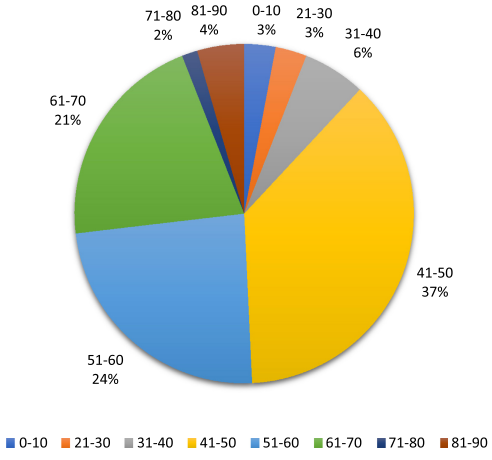

FIGURE 5 Estimated percentage of female teaching staff in OHP schools ($n = 71$).

and programme review were the most commonly reported processes. Similarly, many schools also have a regular process of external quality assurance ($n = 62$, 87.3%), whilst seven schools (9.9%) don't and respondents from two schools (2.8%) were unsure. Most of these schools ($n = 41$, 57.7%) make the results of external quality processes available online.

4 | DISCUSSION

4.1 | Curriculum approaches

The majority of schools report that they have hybrid curricula meaning they use a mix of integrated and discipline-based approaches. This likely aligns to a general trend in OHP education, with increasing support for integrated curricula, which stems back to the 1980s and Harden's recommendations in medical education.[41] Integration may be horizontal (across different themes within the same year of study) or vertical (across different themes and years of study) and a combination of these is termed the spiral curriculum.[42] The reported benefits of integrated curricula include: a reduction in fragmentation of programmes, revisiting topics at increased complexity to embed desired knowledge/skills/attitudes at a higher level, fostering a true interdisciplinary approach to learning and teaching and facilitating curriculum monitoring and evaluation.[41,43] It is noteworthy that only around 20% of schools report using a fully integrated approach – it is plausible that institutions are still transitioning towards a fully integrated approach or may have found a fully integrated approach challenging to implement or perceive it to be undesirable. It would be of interest to carry out further research to understand the mindsets of these institutions as there may be potential barriers or problems with a fully integrated approach that are not readily identifiable in the literature. It is also not clear how fully integrated curricula are delivered in multiple different geopolitical contexts.

4.2 | Curriculum frameworks

More than 90% of schools use national frameworks to guide their PDDP curricula. This figure is largely expected as many European competent authorities and regulators provide curriculum frameworks that schools must adhere to. Schools from Spain, Malta, Cyprus, Denmark and Israel did not report the use of a national framework to inform their curricula. In these contexts, it is not clear what external quality assurance measures are in place, although the absence of a national framework does not necessarily mean that

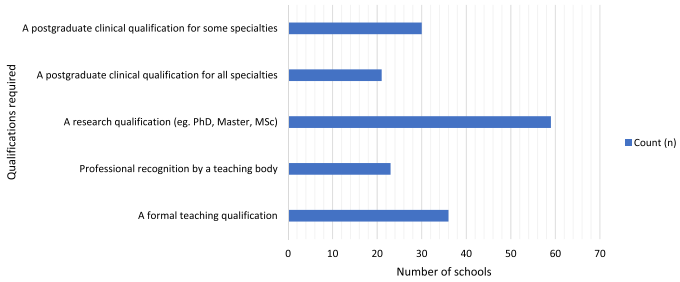

FIGURE 6 Qualifications required when recruiting senior teaching staff (faculty) ($n = 71$).

these processes are inadequate. Most schools report to developing their own curricula locally and may use aids such as international/national/regional frameworks to support this. It is positive that 42 schools report the use of the GED framework as a guide for curriculum development. It is also of interest that over 15% of schools reported using curricula that have been developed elsewhere – this sharing of practice is positive and collaboration across multiple spheres in education may increase efficiency and quality. The free-text responses demonstrated substantial uptake of recent discipline-specific curriculum documents which further supports the calls for the development of other discipline-specific curriculum documents by the GED and O-Health-Edu vision for OHP education.[4,25]

4.3 | Methods of learning and teaching

From the data reported, it appears that there are a wide variety of learning and teaching methods are employed in PDDPs. As expected, didactic and practical exercises are used very often in most institutions. Didactic delivery is defined as 'the direct delivery of teaching material from teacher to student, typically in lecture format with little student engagement'.[3] The use of didactic delivery is an efficient means to deliver information to a large audience – making it a very useful methodology for dental schools. With technological advances, didactic delivery can become interactive and facilitate discussion between educators and students. From the list of learning and teaching methods included in this question (Figure 1), some present formal methods that are easily identifiable by the respondents. As respondents to the questionnaire were one single senior academic member of staff, it is feasible that some of the informal teaching methods (e.g. bricolage, peer-review, self-assessment) may be used more frequently but were not captured in the data. Unfortunately this is an unavoidable consequence of the research methodology employed, by selecting the Dean/Head of School (or a designated individual as recommended by the Dean/Head of School) – the research team feel the data is captured from the source best placed to answer the questions as accurately as possible. It is surprising that some schools do not utilise didactic delivery or practical exercises – due to the practical nature of the profession, it would be of interest to establish what methods are used to replace this learning.

4.4 | Integration of topics of interest

It is recommended that some topics should be longitudinally embedded across the length of the curriculum. These topics are often complex and some fit the definition of a threshold concept.[44] Some topics included in Figure 2 are well established in OHP education and others are more emergent areas of interest. There are published recommendations to support OHP schools in embedding some of these concepts in the curriculum, although they are limited to certain topics.[30,32] These documents largely include learning outcomes and recommendations for learning, teaching and assessment. It is noted that there is an absence of guidance for some topics and existing guidance documents do not always offer explicit examples of practice – this is an area of development for the future. The importance of these topics was also included in the O-Health-Edu vision for OHP education in Europe.[4] It is positive that the vast majority of respondents currently teach or are planning to integrate all of these topics in their curricula. It was expected that most schools longitudinally embed professionalism, critical thinking and evidence-based practice due to the perceived importance of these topics among European competent authorities, regulators and educational bodies.[15,30]

Environmental sustainability and social accountability are less frequently embedded within the curriculum and this is likely due to their more recent emergence as a topic of interest in OHP education. Although it is positive to note that more than 20 schools report to already teaching environmental sustainability longitudinally across their PDDPs. It would be interesting to uncover how these schools have longitudinally embedded this topic or in what guise this topic is perceived to be longitudinally embedded. It is important to note again that these are reported results of what educators feel is being delivered – it is not *necessarily* what schools are doing.

4.5 | Student opportunities for research

Most OHPs schools report that students have opportunities for research within their PDDPs. This does not align to a recent survey of European OHP students, which demonstrated that students largely disagreed that their OHP programmes provide clear guidance on extra-curricular research activities.[45] While this source refers

specifically to extra-curricular activities – there may be disparity in perceptions of opportunities between staff and students. It is impossible to establish the extent to which research in taught in OHP schools from this question alone. There is significant support from students to incorporate research in the curriculum and the student body has supported an open curriculum for research in OHP education.[45] Plans for an additional research domain for the GED are underway.

4.6 | Student opportunities for travel and volunteering

The authors feel it is positive that over 80% of schools reported to providing opportunities for study in another country. Within the European Union, the Erasmus scheme for staff and student exchange is well established and provides a funding stream for studying or working in different countries. It is not clear whether these opportunities allow the students to provide patient care, in the authors experience this varies across Europe.

4.7 | Student opportunities for interprofessional education

The value of IPE is well established in the dental education literature.[4,46–48] IPE may include collaborative learning within the OHP team, wider healthcare team or can extend to trans-professional learning with other professions (e.g. engineering).[49] It is positive that almost 2/3 of schools reported to providing IPE opportunities for their students and over half of these were opportunities with other health professionals. The scope, duration and frequency of these events are not clear. Additionally it is not clear if any of these responses refer solely to combined lectures with other health professionals – this do not really equate IPE with defined learning outcomes and opportunities for collaborative learning across professional programmes.

4.8 | Commencement of clinical activities and average number of clinical sessions

The results from this dataset suggest there is significant variance in the commencement of clinical activities on PDDPs. Apart from observing the delivery of oral healthcare, all other clinical activities – including assisting, delivering preventive, non-invasive and invasive care – largely commence from Year 3 onwards. This likely is a legacy from traditional discipline-based curricula where the first 2 years of PDDPs were dedicated to the basic sciences. Additionally, some schools report that their students commence operative care in Year 5 onwards, although some 6-year PDDPs are included in these data (Figure 3). It is clear that schools vary in their delivery of clinical education, with some schools providing early clinical contact from Year 1 or 2 of PDDPs and incrementally building on this, while other schools may deliver intensive clinical training later in PDDPs. While there is no published research comparing the two approaches, there are suggestions within the literature of a preference to initiate clinical contact early in programmes to develop professional skills and to provide students with experience of their chosen career path.[50–52] There are potential barriers to early clinical exposure that may limit implementation of this approach – this may include a lack of resources (clinical space, patients, increasing student numbers) or challenges with location; with some institutions delivering the early years of PDDPs at different sites.

4.9 | Staff–student ratios in clinical spaces

There are similarities in staff–student ratios in clinical and clinical skills teaching laboratory environments within this dataset. Over 60% of schools reported 1 member of staff to 2–7 students in clinics, with this still being the most common group for clinical skills teaching spaces. However, there are increased frequency of lower staff–student ratios in clinical skills learning environments compared to those for clinical teaching. Higher staff–student ratios will reduce workload in these environments but requires increased resources. This data supplements a previous survey on pre-clinical operative dental skills by Field et al.[33] It is largely accepted that lower staff–student ratios are preferable to support student learning, as access to constructive feedback at regular intervals helps students to learn in these practical environments.[53] However, it is necessary to state that staff–student ratios will be contextual and depend on the clinic, discipline and space available – respondents may have selected the average staff–student ratio for their programme.

4.10 | Access to outreach practice and anatomical dissection

Outreach practice is defined in Articulate as 'dental clinics that allow undergraduate students to provide oral health care to a population geographically distant from the University's main dental school or hospital. On occasion, outreach practices may focus on serving the needs of specific groups of patients'.[3] Access is reportedly high across OHP schools in Europe with almost 70% of schools providing outreach practice opportunities. The benefits of outreach practice are widely reported, with a shift away from hospital-based settings providing students with experience in authentic working environments in a primary oral health service.[54] Outreach practice in community settings has also been reported to improve self-confidence, clinical experience and operator speed.[55,56]

Many schools offer anatomical dissection utilising either physical or virtual methods. There is limited reporting of dissection practices and attitudes in OHP education, although two studies

have demonstrated some support for dissection within individual institutions.[57,58]

4.11 | Access and location of facilities and technology

All respondents provide access to dental clinics, physical libraries, clinical skills teaching laboratories and technical skills teaching laboratories. While support and well-being services are widely available – more than half of these are situated outside the dental school. This may be a concern in contexts where the dental school is located at a significant distance away from the wider university's services, which may make access challenging for OHP students and staff. As OHP programmes are intensive and often stressful – it is necessary to provide easy-to-access support and well-being services to all members of the school.

It is of surprise to the authors that almost 50% of OHP schools reported access to dental VR simulators. This is substantially higher than a previous survey where it was reported that 25% of European schools have VR dental simulators, although the sample size was significantly smaller.[59] While this data states a high number of schools have access to VR simulators, it is not clear if they are used routinely to support learning and skill development in their PDDPs. VR simulation is an emerging topic in OHP education and further development is required to refine its use.[60] There is promising research demonstrating the potential for VR to provide authentic assessment and feedback in controlled situations[61] and in improving self-confidence in complex operative tasks prior to delivering patient care.[62,63] As all respondents to this survey are ADEE member schools and therefore may be more active in the OHP education community – it is possible that this data is an overrepresentation of the true uptake of VR simulators in Europe.

4.12 | Teaching staff (faculty)

OHP schools appear heavily reliant on junior part-time staff and senior full-time staff with these two groups accounting for over 70% of the workforce. Junior part-time staff are often general dentists who work outside of the school for the remainder of the working week. It is concerning that such a high proportion of the workforce are held up by these two groups – with small numbers of full-time junior staff. This is potentially unsustainable or high-risk and may be indicative that institutions are struggling to succession plan effectively. Academic training pathways, that incorporate further teaching, research and clinical training are necessary to develop future academics and sustain the workforce. Funding may be an issue that limits the availability of these posts.

The estimated percentage of female teaching staff within this dataset varied from one school to another with a trend for a higher proportion of female staff in many places. This is not surprising as the World Dental Federation (FDI) states that women make up between 48 and 75% of the dentist workforce in Europe.[64] While there is limited previous data for female numbers in academia, it appears that gender inequality correlates with higher ranking academic and leadership positions in many high-income countries.[65] This appears to be a common and unresolved problem across all health professions.[66,67] Women may form a significant majority of junior staff but when it comes to progress into senior positions the number seem to be lower. This may be related to an age cohort effect but also may be due to increased time constraints in order to comply with academic requirements or to find their place within the institutional political context.

From the data, there appears to be a significant focus on research qualifications when appointing senior teaching staff. Interestingly a postgraduate clinical qualification or teaching qualification are not required in over half of schools. The requirements and terminology around senior teaching staff are likely to vary across Europe, traditionally a research doctorate (PhD) is needed to be appointed as a lecturer but is not needed for senior clinical teachers – where the core focus is teaching and clinical care.

4.13 | Quality assurance processes

Most schools reportedly undertake regular internal and external QA, with external referring to processes outside of the institution and internal referring to those within the institution.[3] The importance of regular QA has been noted in multiple recommendations at a European level.[4,22,25,68] Most free-text responses for internal QA referred to course evaluation, student feedback and programme review. These responses are commonly accepted internal QA processes, and in this sense, it is reassuring that institutional governance is, in most cases, driving the internal quality of programmes.

5 | LIMITATIONS OF THE RESEARCH

The limitations of the methodology employed has been discussed at length in Part 1 of this paper series.

6 | RECOMMENDATIONS

The following recommendations have been developed by the authors in light of the findings across both papers within this series:

- Ascertain how individual countries regulate and define specialist dentists through research and collaboration with stakeholders.
- Institutions should consider succession planning and dedicate resources to developing junior academic members of staff.
- Review the suitability of clinical training across OHP schools in Europe through research and collaboration with stakeholders.
- Develop a curriculum development framework to aid schools in embedding new concepts longitudinally within programmes.

7 | CONCLUSION

As far as the authors are aware, this series of papers are the first attempts to provide a comprehensive overview of OHP education in Europe. In this paper, significant variability in the delivery of clinical education across the European OHP schools included in this dataset has been demonstrated. Promisingly, the dataset showed that the majority of European dental programmes are engaged in providing innovative and scientifically grounded education in order to develop quality future OHPs. Additionally, the dataset elucidates the value of the Graduating European Dentist in curriculum development and demonstrates substantial adoption of outreach and interprofessional education practices. Some concern has been raised regarding the sustainability of the current academic workforce in Europe.

A comprehensive view of the state of OHP education in Europe is not yet *available* but the O-Health-Edu datahub provides a means for all education providers in Europe to contribute data to reach this goal. In the future, as the O-Health-Edu project concludes, ADEE will oversee the functionality and branding of the datahub. It is anticipated that the datahub will be updated and *built* upon over time to continually establish a clearer picture of the state of OHP education in Europe. This is call for collaboration across all institutions and *education* stakeholders to develop OHP education for the future.

CONFLICT OF INTEREST STATEMENT

No conflict of interest has been declared by the authors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Dixon J, Tubert-Jeannin S, Davies J, et al. O-Health-Edu: A viewpoint into the current state of oral health professional education in Europe: Part 2: Curriculum structure, facilities, staffing and quality assurance. *Eur J Dent Educ*. 2024;28:607-620. doi:10.1111/eje.12987

Chapter V – Current Teaching Practice for Environmental Sustainability in Dental Education

Overview

Awareness of the importance of environmental sustainability (ES) in dental education has been increasing, with multiple stakeholders supporting its inclusion in the curriculum [13,15,251,270,273]. However, the presence of ES in existing curricula appears limited. It is unclear if and how dental schools teach this concept in didactic and clinical settings. Additionally, it has been acknowledged that many schools face challenges in embedding ES in the curriculum. However, these challenges have not been extrapolated sufficiently, and potential solutions have not been explored [251,273,274].

The included peer-reviewed manuscript [323]:

> ***Dixon J**, Field J, van Harten M, Duane B, Martin N. Environmental Sustainability in Oral Health Professional Education: Approaches, Challenges, and Drivers—ADEE Special-Interest Group Report. European Journal of Dental Education. 2024 Aug 13 [ONLINE - IN PRINT].*

Explores current teaching practices for ES in dental and oral health professional (OHP) education as an update from the Association for Dental Education in Europe (ADEE) 'Sustainability in Dentistry' special interest group. A mixed methods approach was employed to identify the presence of ES in dental curricula, the teaching methods used, and any barriers and drivers that impact the inclusion of this topic in the curriculum.

The included peer-reviewed manuscript [324]:

> ***Dixon J**, Martin N, Field J. Current practice, barriers and drivers to embedding environmental sustainability in undergraduate dental schools in the UK and Ireland. British Dental Journal. 2024 Nov 1;237(9):723–8.*

Investigates current teaching practice for ES in dental schools in the United Kingdom and the Republic of Ireland. As the GDC's 'Safe Practitioner' framework includes learning outcomes that are specific to ES, a survey was disseminated via the Dental Schools Council to uncover existing teaching practices and drivers and barriers to embedding ES in the curriculum.

Candidate Contribution

The PhD candidate is the principal investigator and first author of both manuscripts and made the most significant contributions to conceptualisation, methodology design, instrument development and piloting, data curation and analysis, write-up, and journal submission. After serving as co-chair for several years, the PhD candidate chaired the 'Sustainability in Dentistry' special-interest group at the annual ADEE conference in Liverpool. This meeting brought together many educators from across the world and served as a pivotal event to raise awareness of the environmental sustainability in dentistry (ESD).

Environmental Sustainability in Oral Health Professional Education: Approaches, Challenges, and Drivers—ADEE Special-Interest Group Report.

Introduction

The ADEE 'Sustainability in Dentistry' special-interest group has been at the forefront of the push to embed ES in dental and OHP education. Previous consensus reports from the group established a need to teach ES. However, further activity was required to understand the current situation and existing challenges.

Aim

This study aimed to (i) identify current teaching practices and approaches to embedding ES in the curriculum in ADEE-attending schools, (ii) explore existing barriers/challenges to incorporating ES in dental education, and (iii) consider potential solutions.

Methodology

The annual special-interest group meeting took place in August 2023 in Liverpool. A mixed-methods approach was employed to collect data and explore responses in further detail. A pre-meeting questionnaire was distributed to all registered attendees to identify current teaching practices for ES and any existing challenges and drivers to embedding this topic in the curriculum. At the in-person meeting, an interactive workshop explored the challenges reported in the pre-meeting questionnaire, and potential solutions were developed through a consensus-based approach.

Results

Thirty-two responses were received for the questionnaire, and 37 attendees were present at the interactive workshop. Most respondents (56%) stated that ES is not currently taught in their institutions. Lectures and seminars were the most reported method to teach ES in

non-clinical spaces. Methods for teaching ES in clinical spaces were less clear, with most responses focusing on raising awareness (n=5) and using more sustainable materials (n=3). Time constraints, a lack of expertise to teach ES, a lack of practical guidance to support educators, limited learning resources for staff and students and resistance from colleagues regarding the relevance of ESD were all commonly reported barriers. Fourteen consensus-based strategies to overcome these barriers were developed.

Relevance

The results of this study demonstrate a clear need for further guidelines on strategies to embed ES in the dental curriculum. Whilst institutions, educators, and students have demonstrated a desire to proceed, there is clear concern about how to deliver this curriculum development practically. Due to the novelty of the topic and the workload required, the special-interest group feels co-creation and sharing resources across institutions is critical. The need to longitudinally integrate ES into all years of the programme has been confirmed. Real-world examples and content guidance are required to facilitate this process for institutions and educators.

European Journal of Dental Education

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ORIGINAL ARTICLE OPEN ACCESS

Environmental Sustainability in Oral Health Professional Education: Approaches, Challenges, and Drivers—ADEE Special-Interest Group Report

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Received: 14 June 2024 | **Accepted:** 25 July 2024

Funding: The authors received no specific funding for this work.

Keywords: dental education | dental hygienists | environmental sustainability | oral health professionals | survey

ABSTRACT

Introduction: This paper reports on the scholarship activity of the 'Sustainability in Dentistry' Special-interest Group (SiG), which met at the Association for Dental Education in Europe (ADEE) annual conference in Liverpool on 25 August 2023. The aim of this study was to (i) identify current teaching practices and approaches to embedding Environmental Sustainability (ES) in the curriculum in ADEE attendee schools and (ii) explore existing barriers/challenges to incorporating ES in dental education and consider potential solutions.

Methodology: A mixed-methods approach was used to fulfil the aims of this study. A pre-workshop questionnaire was used to explore current teaching practices, challenges and drivers of embedding ES in the curriculum. An interactive workshop at the in-person meeting in Liverpool was used to propose key strategies to overcome the most frequent challenges to embedding ES in the curriculum.

Results: The majority of respondents (56%) reported that their institutions do not currently teach ES. Traditional didactic forms of teaching were mostly reported to teach ES in non-clinical environments, and a transition to more environmentally sustainable materials and instruments was the most popular response for clinical teaching. Key barriers to embedding ES in the curriculum were identified, including time constraints and the overloaded curriculum, a lack of expertise/knowledge to teach and lack of practical guidance to support educators, limited learning resources for staff and students and resistance from colleagues regarding the relevance of ES in dentistry. The special-interest group participants proposed strategies to overcome these challenges that centred around 14 themes.

Conclusion: This paper reports recent scholarship activity by ADEE's 'Sustainability in Dentistry' SiG. Key strategies for overcoming the most common challenges to embedding ES in the curriculum are also discussed.

1 | Introduction

Delivering oral healthcare currently results in numerous significant environmental impacts, including carbon emissions, pollution, waste generation and biodiversity loss [1–4]. Research has demonstrated that patient travel and staff commuting are the most important contributors to environmental impacts, as oral healthcare is typically delivered over numerous appointments in small clinics in dispersed locations [5]. In addition, procurement of clinical items, energy and water consumption, and waste generation all contribute significantly to the environmental impact of dentistry [6–8].

There is a significant drive across healthcare to deliver more environmentally sustainable services. Multiple organisations have set goals to mitigate environmental impacts, including national healthcare systems and the universally adopted United Nations Sustainable Development Goals [9, 10]. Numerous stakeholder groups, including the FDI World Dental Federation, are engaged in discussions to deliver environmentally sustainable change in the sector [11–13]. Education has been identified as a critical strategy to achieve these goals, and therefore, Oral Health Professional (OHP) programmes must incorporate Environmental Sustainability (ES) within their curriculum [14–16].

The Association for Dental Education in Europe (ADEE) is leading the drive to embed ES in OHP education through the 'Sustainability in Dentistry' Special-interest Group (SiG). The group met for the first time at the ADEE annual conference in Berlin in 2019, and collaborative activities have led to the publication of two consensus reports [15, 16]. These papers identified a need to embed ES in the curriculum and reported consensus-agreed learning outcomes and teaching and assessment methods for ES. The Graduating European Dentist (GED) task force reviewed these learning outcomes, and they have now been adopted into the web-based curriculum framework (https://adee.org/graduating-european-dentist/graduating-european-dentist-curriculum). The General Dental Council, the national regulator in the United Kingdom, have adopted some of these learning outcomes in their recent Safe Practitioner Framework, meaning that registered OHP schools must teach and assess ES from 2025 [17].

There is limited evidence to suggest OHP schools are currently teaching ES, with the recent O-Health-Edu pan-European survey reporting that over 30% of responding schools do not currently teach this topic at any level [18]. This work did not explore *when* and *how* ES is taught, but it provides important preliminary data. Additionally, other surveys have reported very little experience with ES in OHP school curricula [19–23]. Positively, these surveys reported significant student and educator support for embedding this topic in the curriculum.

Embedding ES in the curriculum presents numerous challenges, and some schools may feel unsure of how to proceed. Some barriers reported in the literature include a lack of time, expertise and resources, although this has not been fully explored [19, 21, 23]. Additionally, previous surveys reported low response rates and received responses from limited geographical areas and institutions.

It is important to understand current practices and challenges across multiple geopolitical areas. ADEE often brings together OHP educators from numerous countries with different regulatory processes [18, 24–26]. The SiG activities to date have focused on needs assessment and developing resources for educators. However, there is a need to identify existing practices, explore current challenges and uncover potential solutions.

This paper reports on the scholarship activity of the 'Sustainability in Dentistry' SiG, which met at the ADEE annual conference in Liverpool on 25 August 2023. The aim of this study was to (i) identify current teaching practices and approaches to embedding ES in the OHP curriculum in ADEE attendee schools and (ii) explore existing barriers/challenges that complicate incorporating ES in dental education and consider potential solutions.

2 | Methodology

This study received ethical approval from the Dentistry Ethics Committee at the University of Sheffield (application number 056060).

A mixed-methods approach was used to achieve the aims of this study. A pre-workshop questionnaire was distributed to all registered attendees of the SiG session in Liverpool to identify baseline data regarding current educational practices, challenges and drivers for embedding ES in the curriculum. The results of this survey informed an interactive workshop at the in-person meeting to explore potential strategies to overcome the most common challenges to embedding ES in the curriculum.

2.1 | Pre-Workshop Questionnaire: Current Teaching Practices, Challenges and Drivers for ES in OHP Education

An 8-item questionnaire was developed de novo due to an absence of relevant published literature in this area. Google Forms was used to write and share the questionnaire. A range of answer options were used depending on the question type, including open- and closed-ended questions. The questions were separated into four sections:

- Respondent's home institution country (1 question).
- Current teaching approaches for ES in non-clinical and clinical environments (4 questions).
- Existing challenges to embedding ES in the curriculum (2 questions).
- Existing drivers that support embedding ES in the curriculum (1 question).

The questionnaire was piloted with five academics from different European countries to ensure face and content validity. The survey link was shared with the working group, and responses were gathered via email. Minor amendments were made to improve the clarity of language and ease of understanding.

The questionnaire was distributed to all attendees who pre-registered for the SiG via the ADEE annual conference app. All potential respondents were emailed twice, the first 2 weeks before and again 3 days before the in-person meeting. Attendees to the SiG were also invited to complete the survey at the start of the session; this was necessary as not all attendees pre-registered for the event. No personal data was collected, as all responses were anonymous. Informed consent was gained at the start of the questionnaire, and a participant information statement was provided.

Descriptive statistics were used to analyse all close-ended questions, and the data was presented in tables and charts. Content analysis was used to analyse the free-text responses. This method codes and groups all responses according to frequency. Three trained researchers discussed and agreed upon the analysis and data presentation.

2.2 | Interactive Workshop: Exploring Existing Challenges and Proposing Solutions

All attendees at the SiG meeting in Liverpool participated in the workshop discussion. To provide context for discussion, the results of the pre-workshop questionnaire were presented at the start of the meeting. The aim of this session was to discuss existing challenges to embedding ES in the curriculum and propose potential solutions. Therefore, the first part of the workshop focused on reviewing the responses to the 'Existing challenges that make embedding ES in the curriculum complex' questions. The most reported barriers from the pre-workshop questionnaire (those with over 40% frequency) were used in the workshop and participants were asked to propose strategies to overcome these challenges.

Participants were invited to submit their thoughts via the interactive electronic platform WooClap (https://www.wooclap.com) to gather individual responses. For each barrier, participants were asked to respond to the question '*What strategies may help to overcome the barrier?*' in free-text format. The responses were visible to all attendees and were used to inform further group discussion. One researcher transcribed the key themes identified in the discussions to add context to the individual responses provided via WooClap. The individual responses and group discussion notes were analysed via thematic analysis, as described by Braun and Clarke [27]. This methodology extracts and organises data into themes that are based on the importance in the dialogues rather than a purely frequency-based approach.

3 | Results

3.1 | Pre-Workshop Questionnaire: Current Teaching Practices, Challenges and Drivers for ES in OHP Education

Thirty-two responses were received for the questionnaire. The responders were based in 26 different higher education institutions and 18 countries worldwide (Table 1). One response was received from an additional stakeholder (professional body).

Over 56% of responding institutions do not currently teach ES (Figure 1). Within this group, 33% of responses stated that they have plans to teach ES soon. Of the respondents that teach ES, 12.5% currently have specific learning outcomes for ES, while 31.3% teach ES without dedicated learning outcomes.

Regarding the most appropriate strategy to embed ES in the undergraduate curriculum, 50% of respondents selected '*ES forms a part of our teaching in all years of our programme*' (Figure 2). Additionally, a significant number of respondents (40%) stated that ES is delivered as a single or group of lectures, and two respondents (10%) deliver a standalone course for ES.

TABLE 1 | Responding countries to the pre-workshop questionnaire.

Responding country	Number of responses
United Kingdom	6
Portugal	4
Netherlands	3
Spain	3
Georgia	2
Australia	1
Belgium	1
Cambodia	1
Denmark	1
Estonia	1
Germany	1
Israel	1
Italy	1
Malta	1
Mexico	1
Oman	1
Romania	1
Sweden	1
Not stated	1
Total	32

Lectures, seminars, workshops and student-led projects ($n = 5$) were the most reported teaching methods used in non-clinical environments (Table 2). Raising awareness in clinical spaces ($n = 5$) and using more sustainable materials, instruments or other clinical items ($n = 3$) were the most reported approaches to teaching ES in clinical spaces (Table 3). Six responses were removed from Table 3 due to the responses falling into non-clinical teaching methods.

Time constraints and the overloaded curriculum were major challenges reported by almost 70% of respondents (Figure 3). A lack of knowledge/expertise to teach ES (59%), a lack of practical guidance to support educators (47%), limited learning resources for educators or students (44%) and resistance from colleagues regarding the relevance of ES in dentistry (44%) were other commonly reported barriers. Additional barriers from the free-text responses included cost/finances ($n = 3$) and technology in prosthodontics ($n = 1$).

Support and policy from local universities ($n = 7$) were the most reported drivers to embed ES in the curriculum (Table 4). Alignment with worldwide trends and societal expectations ($n = 6$) and no reported drivers or 'unsure' ($n = 5$) were other common responses, in addition to staff engagement and support ($n = 4$), ADEE SiG activities ($n = 4$), and activities by other professional bodies for ES ($n = 4$).

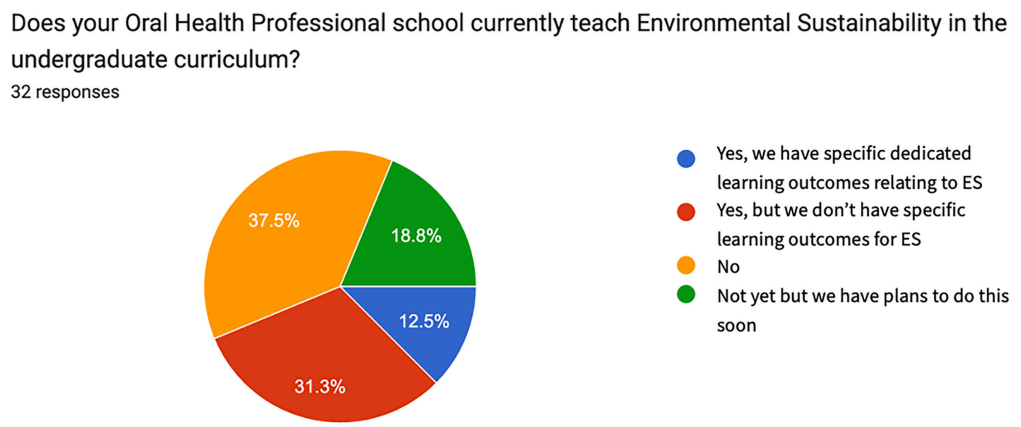

FIGURE 1 | A pie chart demonstrating current teaching practices for environmental sustainability in the undergraduate curriculum.

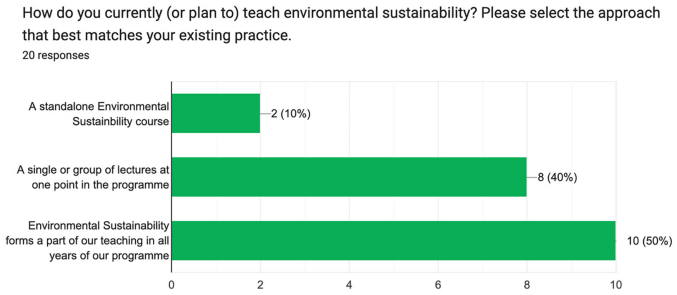

FIGURE 2 | A bar chart demonstrating current or planned approaches to embedding environmental sustainability in the undergraduate curriculum.

3.2 | Interactive Workshop: Exploring Existing Challenges and Proposing Solutions

Thirty-seven participants contributed to the interactive workshop. The participants were based in similar countries to those who completed the pre-workshop questionnaire (Table 1), although there are some differences between the two groups. Participants in the interactive workshop also came from institutions based in France, New Zealand, Saudi Arabia, Switzerland and the United States of America. Respondents to the pre-workshop questionnaire from Cambodia, Georgia, Italy and Sweden did not participate in the interactive workshop.

The discussion in the workshop centred around the five most reported barriers in the pre-workshop questionnaire:

- Time constraints and the overloaded curriculum:
- A lack of expertise/knowledge to teach ES.
- A lack of practical guidance to support educators.
- Limited learning resources for staff and students.
- Resistance from colleagues regarding the relevance of ES in dentistry.

Thematic analysis of the responses and discussions in the workshop identified 14 themes across the five barriers. The themes for each barrier are presented in Table 5.

4 | Discussion

The scholarship activity provided in this update of SiG activity provides essential information for policymakers, educational organisations, local curriculum committees and individual educators. The mixed methods approach described in this paper has enabled an overview of current educational practices, barriers and drivers and explored key strategies to overcome core challenges in embedding ES in the curriculum.

4.1 | Current Teaching Practices and Approaches for ES

A significant proportion (56%) of respondents reported that they are not currently teaching ES, which highlights the need to overcome the identified challenges that OHP schools face. The results largely align with previous surveys, which also report little experience of ES. However, previous student-led surveys

TABLE 2 | Free-text responses to current or planned learning and teaching methods for environmental sustainability (ES) in non-clinical environments.

Learning and teaching method (non-clinical)	Number of responses
Lectures	5
Seminars/workshops	5
Self-directed learning/student-led projects/groupwork	5
Embedded into all teaching events where appropriate	3
Central university department delivers teaching on ES	2
Online module/training package	1
Culture change (e.g., promoting home-based positive ES attitudes)	1
Teaching hospital delivers teaching on ES	1
Case studies, reflective discussions	1
Elective course	1
Unsure	1

TABLE 3 | Free-text responses to current or planned learning and teaching methods for environmental sustainability (ES) in clinical environments.

Learning and teaching method (clinical)	Number of responses
Raising awareness in clinical spaces (e.g., facilitating recycling, planning sessions to reduce travel)	5
Using sustainable materials/instruments on clinic	3
Incorporate into clinical grading/marking criteria	2
Still finalising delivery method/unsure/in discussion	2
Case-based discussion and treatment planning	2
Clinical audits	1
Reflective log that incorporates ES	1
Focus on high-quality preventive oral healthcare delivery	1
Clinical skills laboratory teaching	1

reported little, if any, exposure to ES in the curriculum, and this survey identifies that 44% of respondents teach ES in some capacity. This suggests that change may be starting to occur, although slowly.

The majority of respondents plan to teach ES longitudinally across all years of OHP programmes, and this aligns with the recommendations proposed by the SiG and associated published literature [15, 16, 28]. This approach should reduce concerns regarding adding new events into an already overloaded curriculum and allow for frequent reinforcement of this challenging construct. A significant, albeit lesser proportion, of responses proposed teaching ES as a single or group of lectures at one point in the programme. While this may be suitable in some contexts, it is unclear if this approach will support learners in developing an understanding that ES is a core component of all aspects of oral healthcare delivery.

The teaching methods explored in the pre-workshop questionnaire demonstrated that traditional forms of didactic teaching, such as lectures and small group sessions, were popular options for teaching ES in non-clinical environments. Some responses referred to incorporating ES into *existing* learning events as opposed to adding new lectures that focus exclusively on ES. This aligns with recent work by Dixon et al. that developed evidence-based and subject-specific content statements for ES, with the idea that these can be directly incorporated into local contexts, perhaps in the form of a slide deck [28]. Some responses suggest that other methods of teaching are employed to teach ES, including student-led learning, culture change initiatives and reflective projects. It is promising that all responses correspond with the methods proposed in the SiG's consensus report by Field et al. [16].

Current teaching in clinical environments is less clear, with significantly fewer applicable responses provided for this question. Responses largely centred around making changes to adopt more environmentally sustainable materials and instruments or facilitating recycling of non-contaminated single-use plastics. Interestingly, there was less focus on teaching the benefits of good quality preventive and operative oral healthcare and treatment planning, even though these points have been a key focus of recent publications and have been demonstrated to provide significant environmental benefits [13, 28, 29].

4.2 | Barriers to Embedding ES in the Curriculum and Potential Solutions

Multiple challenges to embedding ES in the curriculum have been identified. These will be considered individually alongside the proposed solutions by the workshop participants.

4.2.1 | Time Constraints and the Overloaded Curriculum

Educators feel that the most significant challenge to embedding ES in the curriculum is time constraints and the overloaded curriculum. The solutions proposed by the SiG were to embed ES into the existing curriculum across all years of study, refine the existing curriculum to create space and reduce repetition and start with small steps across all years of study. The benefits of embedding ES longitudinally across all years of programmes, both in terms of curriculum time and educational rationale, have been discussed previously in this manuscript and in associated publications [16, 28]. The approach proposed

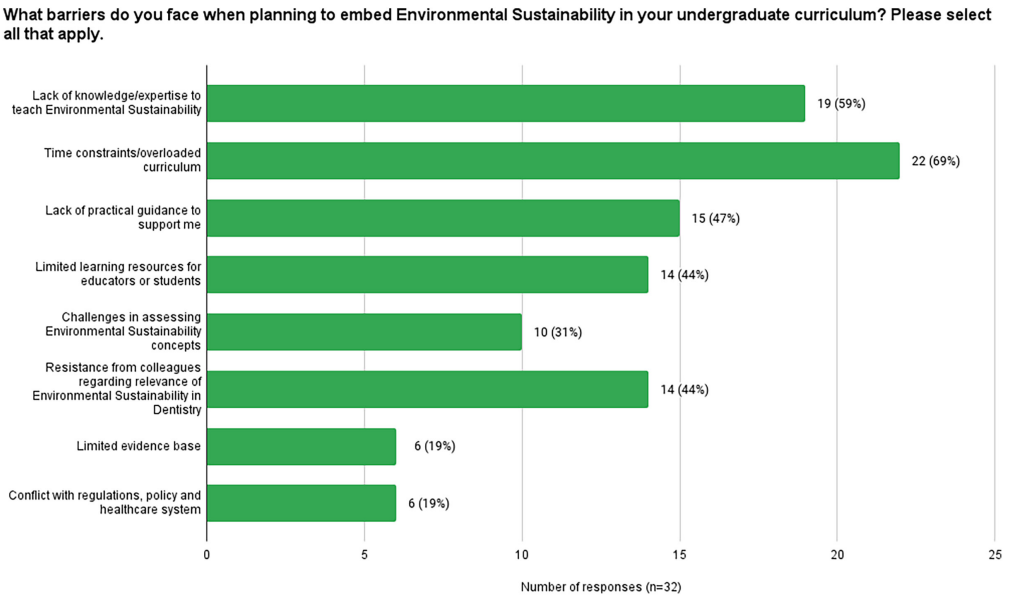

FIGURE 3 | A bar chart demonstrating responses to the most common challenges to embedding environmental sustainability in the undergraduate curriculum.

TABLE 4 | Content analysis of the free-text responses for drivers to embedding environmental sustainability (ES) in the undergraduate curriculum.

Driver/facilitator	Number of responses
University policy	7
Worldwide trend/societal expectations	6
No drivers reported or unsure	5
Staff engagement and support	4
ADEE 'Sustainability in Dentistry' SiG activities	4
Activities by other professional bodies for ES	4
Student engagement and support	3
Local staff as leaders/champions of ES	3
Emerging topic at conferences	2
Published learning outcomes for ES	1
Audit results	1
Emergence of digital workflows	1

by Dixon et al. [28] should allow for minimal disruption as the content statements can be directly incorporated into existing teaching events in the form of single or multiple statements or '*take-home messages*' for ES.

A curriculum development cycle should allow for regular review of teaching across the length of OHP programmes. This is essential to ensure that curricula are fit for purpose in meeting the demands of a changing profession and are 'sustainable' through effective use of resources. Curriculum development should allow for refinement of content, ensuring all essential components are covered but avoiding unnecessary repetition of components. The outcomes of this process may provide opportunities or 'space' to embed ES in the existing curriculum.

Due to the challenges identified in this and previous studies, it may be necessary for OHP schools to start with small steps and build on these foundations over time. There may be '*easy wins*' where ES can be embedded into current events, and there may be potential to do this quickly and with minimal disruption. Other learning events may be too complex to complete in a short time frame and can be incorporated later after reflecting on what has been learned in these early steps. Sharing of these practices among institutions will allow for a collaborative solution to overcome core issues in embedding some elements of ES in OHP education.

4.2.2 | A Lack of Expertise/Knowledge to Teach ES

Concerns from educators regarding a lack of expertise or knowledge to teach ES have been widely reported in the healthcare literature [19, 21, 30–34]. It is acknowledged that the subject of ES is foreign to many, and teaching this across the length of the programme may be intimidating for some educators. It is anticipated that a significant proportion of ES teaching can be delivered by non-experts who "learn alongside the learners" to improve awareness and knowledge of this critical issue [35, 36].

TABLE 5 | Themes identified to overcome the most common barriers to embedding environmental sustainability (ES) in the undergraduate curriculum.

Barriers	Identified 'Themes' as key strategies
Time constraints and the overloaded curriculum	Embed ES into the existing curriculum across all years of study
	Refine the existing curriculum to create space and reduce repetition
	Start with small steps across all years of study
A lack of expertise/ knowledge to teach ES	Develop and deliver effective faculty/ staff development sessions for ES
	Collaborate with colleagues and educational bodies external to the university
	Student collaboration and co-creation
A lack of practical guidance to support educators	External collaboration, sharing of practice
	Publish examples of practice and guidance
Limited learning resources for staff and students	Develop and share resources among institutions
	Centralised collection of resources (e.g., ADEE webpage)
	Student co-creation of resources
Resistance from colleagues regarding the relevance of ES in dentistry	Facilitate and support further education
	Incorporate ES into mandatory training
	Set good examples—senior staff and ES champions

Developing effective staff development sessions with easy-to-use and accessible resources will improve awareness and knowledge. It is important for educators to be aware that relatively small changes to our education processes and clinical care can mitigate environmental impacts significantly, and actually, good quality oral healthcare is good for the patient, the profession and the environment [13, 28]. Staff development should consider fundamental concepts, such as climate change, the impact of climate change on health, how healthcare contributes to climate change, more environmentally sustainable strategies for care delivery and educational strategies to embed ES in the curriculum [37, 38].

The SiG participants proposed co-creating resources between staff and students, which is particularly relevant for this emerging topic and was also proposed in the previous consensus report [16]. ES is a transdisciplinary issue, and sharing resources among similar programmes or institutions may significantly reduce workload, avoid duplication and improve the quality of teaching [31, 35, 39].

4.2.3 | A Lack of Practical Guidance to Support Educators

Participants reported a lack of guidance to support educators in embedding a topic like ES in the curriculum. Although ES has emerged as an important component of OHP education and it is already incorporated into some curriculum frameworks, there is limited guidance to demonstrate how (strategies) it should be done and what (content) should be taught. The recent publication by Dixon et al. utilised a mixed methods approach of focus groups and extensive stakeholder consultation to provide guidance on this [28]. However, this was published after the data was collected from the SiG. A real-world example of embedding ES within the constraints of an OHP curriculum is yet to be published.

The key themes proposed by the SiG members include external collaboration, sharing good practices and publishing these in a peer-reviewed journal or making them available online in a central resource hub.

4.2.4 | Limited Learning Resources for Staff and Students

The presence of learning resources for educators and students about ES in dentistry and oral healthcare is steadily increasing, although it is acknowledged that further work is needed. Recent works, including the publication of the FDI World Dental Federation's MOOC (massive open online course) on Sustainability in Dentistry, the previously mentioned work based on ES curriculum content and strategies, a textbook and previous SiG consensus reports, are major developments in this area. Table 6 provides easy-to-access links to these resources.

The themes proposed by the SiG members to overcome this challenge were to develop and share resources among institutions, create a centralised collection of resources and student co-creation of resources. These points have all been covered earlier in the discussion.

4.2.5 | Resistance From Colleagues Regarding the Relevance of ES in Dentistry

Resistance from colleagues regarding the relevance of ES in the curriculum has been sparsely reported in other publications [31, 32]. However, the results from SiG members suggest that this is a common concern for many educators. It is acknowledged that climate change can be a polarising topic; however, airing open discussions with colleagues regarding the benefits of an environmentally sustainable approach to oral healthcare should extend beyond climate change; there are significant benefits for patients, the profession and the environment. Holding regular staff development updates on ES may help increase staff knowledge of ES and reduce scepticism.

Previous publications have demonstrated that active staff members, whether through research or teaching, are key drivers of change [19, 20]. Environmentally sustainable change will not be a quick process, but setting good examples and embedding ES in

TABLE 6 | Recent resources to support staff and student learning of environmental sustainability (ES) in dentistry and oral healthcare.

Resources for ES in dentistry and oral healthcare	Link
FDI World Dental Federation's MOOC (open access)	bit.ly/FDI-ES-MOOC
ADEE Consensus report on learning outcomes and methods of teaching and assessment for environmental sustainability (open access)	bit.ly/ADEE-ES-LO
Evidence-based, subject-specific content statements for environmental sustainability (open access)	bit.ly/ES-CONTENT
Sustainable dentistry—making a difference	https://link.springer.com/book/10.1007/978-3-031-07999-3
Consensus on Environmentally sustainable oral healthcare: A joint stakeholder statement (open access)	https://universitypress.whiterose.ac.uk/site/books/filter/3328/

education, clinical practice and research will hopefully increase cooperation among all staff members.

4.3 | Drivers to Embedding ES in the Curriculum

Positively, numerous drivers have been identified that support embedding ES in the curriculum. University policy and support are proving to be a major driving force behind the push to embed ES in OHP curricula. The impact of wider societal expectations on driving curriculum change is notable, in addition to staff and student engagement and the activities of professional bodies including the Sustainability in Dentistry SiG.

4.4 | Future Activities

The Sustainability in Dentistry SiG has developed several key resources throughout its term, including establishing a need, proposing specific learning outcomes and teaching and assessment methods for ES, and now identifying current practices, challenges and drivers to embedding ES in the OHP curriculum. It has also proposed key strategies to overcome the frequently reported challenges.

The SiG members have identified a clear need for future activities, perhaps in a community of practice through ADEE. Almost 80% of members proposed developing a series of examples of good practice for teaching and assessing ES, and over 60% supported developing a curriculum development model to demonstrate how to embed ES longitudinally across programmes.

5 | Conclusion

This paper reports recent scholarship activity by ADEE's 'Sustainability in Dentistry' special-interest group, which involved a mixed-methods approach to uncovering existing teaching practices, challenges and drivers to embedding ES in OHP curricula. Most respondent schools do not currently teach ES in any form, although many have plans to do this soon. Key barriers have been identified to embedding ES in the curriculum, including time constraints and the overloaded curriculum, a lack of expertise/knowledge to teach and lack of practical guidance to support educators, limited learning resources for staff and students and resistance from colleagues regarding the relevance of ES in dentistry. The special-interest group participants proposed strategies to overcome these challenges that centred around 14 themes.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting this study's findings are openly available in the University of Sheffield Research Data Repository at https://doi.org/10.15131/shef.data.26502637, under the terms of the Creative Commons Attribution (CC BY-NC 4.0) licence.

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Current Practice, Barriers and Drivers to Embedding Environmental Sustainability in Undergraduate Dental Schools in the United Kingdom and Ireland

Introduction

The recent publication of the GDC's Safe Practitioner Framework has mandated the inclusion of ES in undergraduate OHP curricula in the United Kingdom (UK) by 2025. Individual responses to the consultation process of the new learning outcomes by the GDC suggest that some schools face challenges in embedding this topic [325]. It is uncertain if UK and Irish dental schools currently teach ES and what teaching methods are used. Additionally, drivers and barriers to this curriculum integration are not evident within this geographical context.

Aim

This study aimed to:

i. Explore existing teaching of ES within UK and Irish undergraduate dental curricula.
ii. Illustrate the challenges and drivers of integrating ES in dental education.

Methodology

A survey was developed *de novo* due to an absence of literature in this area. After piloting with five academics from across the UK, eight items were included in the final survey. The items aimed to acquire information on demographics (the responding institution), existing teaching approaches for ES in clinical and non-clinical environments, challenges that complicate teaching ES and drivers that support teaching ES. The survey was disseminated with the support of the Dental Schools Council in the UK, and all schools that deliver undergraduate dentistry programmes in the UK and Ireland were invited to participate. Deans/Heads of School, Directors of Education or other senior academic staff

were invited to complete the survey on behalf of their school. Data was analysed through descriptive statistics and content analysis (free-text answers).

Results

Eighteen responses were received, representing a 100% response rate from the intended population. Most schools (56%) currently do not include ES in the curriculum. Dedicated learning outcomes for ES are present in only three dental schools in the UK and Ireland. Traditional didactic means (lectures and seminars) were favoured by most to teach ES in non-clinical environments. Teaching ES in clinical environments appears more challenging, with most responses (n=5) stating that plans for teaching in this space had not been finalised. A lack of curriculum space (90%) was the most reported challenge to embedding ES in the curriculum. University support, inclusion of ES in other stakeholder guidance and staff and student support were the most commonly reported drivers for change.

Relevance

This study provides context by establishing baseline data regarding current practices, drivers, and barriers for ES in UK and Irish dental education. Dental schools value the inclusion of ES in the curriculum but are still determining how to approach this, especially in clinical spaces. A lack of curriculum space, knowledge limitations regarding ES, a lack of resources to support curriculum integration, conflict with clinical policies and challenges in assessing ES are reported barriers that must be overcome. By understanding the challenges that institutions face in teaching this ES, stakeholders can develop tailored guidance to mitigate these challenges.

Current practice, barriers and drivers to embedding environmental sustainability in undergraduate dental schools in the UK and Ireland

Jonathan Dixon,*[1] Nicolas Martin[1] and James Field[2]

Key points

- Environmental sustainability is an emerging topic in undergraduate dental curricula.
- There is significant support from universities, staff, students and regulators to embed environmental sustainability in the curriculum.
- Most dental schools are not currently teaching this topic; however, many have plans to do so after the recent General Dental Council learning outcomes update.
- Many schools are facing challenges in teaching this topic in clinical environments.

Abstract

Aims This study aimed to: i) identify current teaching practice and approaches to embedding environmental sustainability (ES) in the undergraduate dental curriculum in the UK and Republic of Ireland (ROI); and ii) uncover existing barriers and drivers to incorporating ES in dental education.

Methods A questionnaire was developed and distributed to all dental schools in the UK and ROI in the form of an online survey. The intended respondents were deans, heads of schools, directors of education, or senior academics of all dental schools in the UK and ROI that deliver undergraduate dentistry/dental surgery programmes.

Results In total, 18 dental schools responded to the survey, representing a response rate of 100% from the intended respondents. Note 56% of dental schools do not currently teach ES. Time constraints and a lack of knowledge and learning resources were the most reported barriers.

Conclusion Currently, ES is not taught in most dental schools in the UK and ROI. Many schools face challenges in finalising the delivery modalities of ES teaching, particularly in clinical environments. Numerous barriers have been identified that complicate embedding this topic in the curriculum. Positively, universities, staff, students and the recently published learning outcomes are driving impactful change across the sector.

Introduction

Environmental sustainability (ES) is a growing concern in dentistry, with research demonstrating that delivering oral healthcare, in its current form, is unsustainable.[1,2,3,4,5] The most significant contributors to environmental impacts are patient travel and staff commute; procurement of equipment; instruments and dental materials; energy and water use; and waste disposal. Multiple healthcare organisations have set environmental goals, including the NHS in England and their commitment to achieve net zero by 2040.[6] Achieving these goals will require a significant change in attitudes and behaviours across all healthcare professions.

Education at all levels of the oral health profession has been identified as a key strategic approach to deliver environmentally sustainable change.[4,7] The Association for Dental Education in Europe (ADEE) have been leading the incorporation of ES in undergraduate education through a 'Sustainability in Dentistry' special interest group, which has published two consensus reports.[8,9] These papers both established the need to embed ES in dental education, and proposed learning outcomes and teaching and assessment methods specifically for ES. The FDI World Dental Federation has also been a key stakeholder in supporting ES change in the profession, with the publication of a consensus statement that brought together multiple partners from all sectors of the profession, including industry.[10] This is supported by a 'sustainability in dentistry' toolkit and infographic.[11] Additionally, the FDI World Dental Federation have published an open access Massive Open Online Course (MOOC) that aims to educate the profession at all levels, from students to qualified professionals.[12]

The undergraduate dental curriculum must respond to emerging challenges, whether from societal pressures, new professional developments, or educational rationales and innovations. There is a strong desire from oral health professional students to include ES in their curriculum but with an element of nervousness that this should not provide additional time pressures or course workload.[13,14,15,16,17] This is matched with significant support from academic staff.[8,9,13,16,17] The inclusion of ES in the dental curriculum is now imminent in the UK, as the General Dental Council have

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Refereed Paper.
Submitted 7 May 2024
Revised 26 June 2024
Accepted 2 July 2024
https://doi.org/10.1038/s41415-024-8011-6

adopted several learning outcomes published by the ADEE special interest group in the recent *The safe practitioner* framework.[18] The General Dental Council have mandated compliance with the new framework for all graduates by 2030.

It is unclear if dental schools are currently teaching ES, with little evidence outlining current practice. It is, therefore, anticipated that some dental schools may be struggling to teach and assess this subject matter.[19] Furthermore, a recent paper exploring a wide range of curriculum practices across Europe identified limited evidence of ES teaching in dental schools.[20] Multiple surveys exploring academic staff and student opinion have been published and generally report very little experience of ES in the curriculum.[13,14,15,16,17] Three of these studies also report some barriers that complicate the inclusion of ES in dental education; although, the limited response rate, number of institutions included and closed-ended questions are reported limitations.[13,16,17]

There is an appreciation that the evidence that supports our current understanding of the perceived challenges and the proposed solutions is derived from a relatively small number of higher education institutions. While there is a logical desire to generalise this body of knowledge across all institutions, we recognise that this is not necessarily correct and that there is a need to uncover existing practices and barriers across the UK and Republic of Ireland (ROI) as a whole. This study aimed to: i) identify current teaching practice and approaches to embedding ES in the undergraduate dental curriculum in the UK and ROI; and ii) uncover existing barriers that complicate, and drivers that facilitate, the inclusion of ES in dental education.

Methodology

This study received ethical approval from the Dentistry Ethics Committee of the University of Sheffield (application number 056060). An eight-item questionnaire was developed and distributed to all dental schools in the UK and ROI in the form of an online survey (Google Form). The questions were conceptualised de novo by the authors due to an absence of previous research in the area. The question types and response options were informed by previous research. A range of multiple-choice, 'yes/no' and free-text responses were used as appropriate to the question and construct asked (Table 1). The questions were separated into four sections:

- Responding institution
- Current teaching approaches for ES in non-clinical and clinical environments
- Existing barriers that complicate embedding ES in the curriculum
- Existing drivers that support embedding ES in the curriculum.

Table 1 The survey questions and response options

Question	Response options
Please state the name of your institution and the country in which it is based	Free text
Does your dental school currently teach ES in the undergraduate curriculum?	• Multiple choice (single selection): • Yes, we have specific dedicated learning outcomes for ES • Yes, but we don't have specific learning outcomes for ES • Not yet but we have plans to do this soon • No
How do you currently (or plan to) teach ES? Please select the approach that best matches your existing practice	• Multiple choice (single selection): • A standalone course for ES • A single or group of lectures at one point in the programme • ES forms part of our teaching in all years of our programme
Please detail the methods you use (or plan to use) to teach ES in non-clinical environments	Free text, no limits
Please detail the methods you use (or plan to use) to teach ES in clinical environments	Free text, no limits
What barriers do you face when planning to embed ES in your undergraduate curriculum?	• Checkboxes (select all that apply) • Lack of knowledge/expertise to teach ES in dentistry • Time constraints/overloaded curriculum • Lack of practical guidance to support me • Limited learning resources for educators and students • Challenges in assessing ES concepts • Resistance from colleagues regarding the relevance of ES in dentistry • Limited evidence base for ES in dentistry • Conflict with regulations, policy and healthcare system
Do you face any additional barriers that are not listed in the previous question?	Free text, no limits
Please list the drivers/facilitators that have supported your approach or plans to embed environmental sustainability in your undergraduate curriculum	Free text, no limits

The survey was tested for face and content validity with a group of five academics from three dental schools in the UK and ROI. The group were asked to access and complete the questionnaire via the online platform and provide comments via email. A final draft version of the questionnaire was developed considering the responses to improve clarity of language and ease of understanding.

The intended respondents were deans, heads of schools, directors of education, or senior academics of all dental schools in the UK and ROI that deliver undergraduate dentistry/dental surgery programmes, as recognised by the General Dental Council of the UK and the Irish Dental Council. At the time of the survey, this was 18 dental schools. The survey was supported and distributed by the Dental Schools Council to dental schools in the UK and ROI. It was requested that the deans, heads of schools, or directors of education complete the survey where possible, unless they identified a designated individual that was best placed to answer the questions (eg school sustainability champion, senior academics in strategic positions). In addition to this recruitment stream, the authors directly contacted the institutions that did not respond to Dental School Council request on one further occasion. No further reminders were sent. All responses were anonymous, no personal data was collected and informed consent was gained at the start of the survey through the provision of a participant information statement and consent form.

The close-ended questions were analysed through descriptive statistics and were presented in tables and charts. The free-text responses were analysed through content analysis, where responses were coded, quantified and presented in tables to illustrate frequency of responses.

Results

In total, 18 dental schools completed the survey from October 2023 to January 2024, representing a 100% response rate from the intended respondents. One school provided two different responses, potentially due to delegation or overlap from the initial invitation email and the follow-up. The two responses were collated on the master spreadsheet to enable a single response from the school and to avoid omitting key information from two different responders. For the double response, the open-ended responses were identical and the barriers and free-text responses were combined; no data was deleted.

Current teaching approaches for ES in non-clinical and clinical environments

Ten dental schools (55.6%) reported that they do not currently teach ES; although, five of these schools (27.8%) plan to do this soon (Fig. 1). Five schools (27.8%) currently teach ES without dedicated learning outcomes and three schools (16.7%) have specific learning outcomes for ES.

Of the 13 schools that currently teach or have plans to teach ES, over 60% (n = 8) of respondents reported that ES should form a part of teaching in all years of undergraduate dental programmes (Fig. 2). From the remaining schools, three deliver a single or groups of lectures at one point in the programme and two schools propose a standalone ES course.

Lectures (n = 7) were the most reported method to teach ES in non-clinical environments (Table 2). Smaller group teaching in the form of tutorials or workshops (n = 4) were also reported by multiple dental schools. At the time of completion of the survey, four dental schools were finalising their delivery method for ES in non-clinical environments and five schools reported the same for clinical settings (Table 3). Three schools reported to focusing teaching on the environmental benefits of delivering high-quality oral healthcare as a strategy for teaching ES in clinical spaces.

Existing barriers that complicate embedding ES in the curriculum

Almost 90% of dental schools (n = 16) reported time constraints and the overloaded curriculum as a major barrier to embedding ES in the undergraduate curriculum (Fig. 3). A lack of knowledge/expertise to teach ES in dentistry (n = 9), limited availability of learning resources for educators and students (n = 8), conflict with regulations, policy and healthcare systems (n = 8), challenges in assessing ES concepts (n = 8) and a lack of practical guidance to support educators in embedding ES (n = 7) were also commonly identified barriers.

Fig. 1 A pie chart demonstrating current teaching of ES in the undergraduate curriculum in the UK and ROI

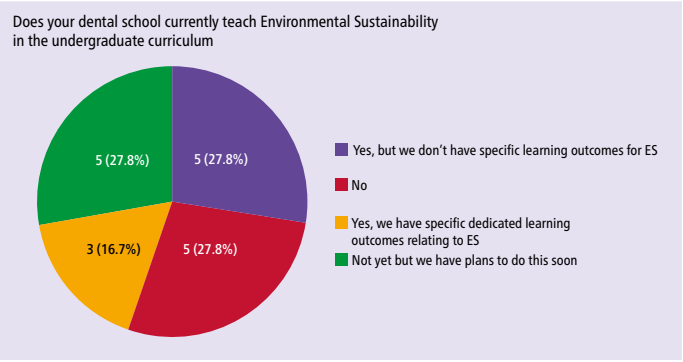

Fig. 2 A bar chart demonstrating current or planned approaches to teaching ES in the undergraduate curriculum

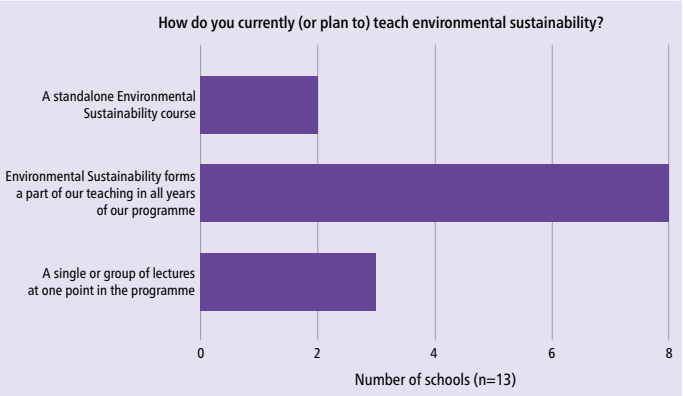

Table 2 Free-text responses to current or planned learning and teaching methods for ES in non-clinical environments

Learning and teaching method (non-clinical)	Number of responses
Lectures	7
Tutorials/workshops	4
Still finalising delivery method/unsure/in discussion	4
Online module/training package	2
Problem-based learning	2
Self-directed learning/projects	2
Embedded into all teaching events where appropriate	1
Culture change (eg shared spaces)	1
Plenaries/teaching event briefing	1

Additional barriers identified through free-text responses were cost (n = 3), awaiting publication of an updated national curriculum framework (n = 1) and the absence of an ES strategy from the associated hospital trust (n = 1).

Existing drivers that support embedding ES in the curriculum

The most reported driver supporting embedding ES in the curriculum was the influence of local higher education institutions (n = 9) and the incorporation of ES into university strategies and policies (Fig. 4). The incorporation of ES into the national curriculum (n = 6), student (n = 5) and staff (n = 5) engagement and support, and local staff researchers as leaders of ES (n = 3), were also commonly reported drivers.

Discussion

This study aimed to report current practice, barriers and drivers to embedding ES in the undergraduate dental curriculum in the UK and ROI. The incorporation of ES learning outcomes into the General Dental Council's *The safe practitioner* framework mandates teaching and assessment of this topic from September 2025. The date of implementation for these changes is proving to be a real challenge, as over 50% of dental schools have not yet included ES in their local curriculum.

Current teaching approaches for ES in non-clinical and clinical environments

Most schools perceive that embedding ES into all years of the dental programme is the most appropriate curricular approach. This aligns with the recommendations set out by the ADEE consensus documents on ES.[8,9] The attitudinal or value-based learning required for ES is similar to topics such as professionalism, which is already embedded into curricula in a longitudinal manner, with vertical and horizontal integration.[21,22] Standalone courses or single events at one point in the curriculum may be feasible in some institutions but it is unlikely to promote longitudinal learning of complex constructs like ES. Achieving meaningful changes in attitudes and behaviours is more likely to result from incremental learning that builds from simple to more sophisticated messages over time.

Dental schools appear better prepared to teach ES in non-clinical environments, with multiple methods reported in this survey. Didactic approaches, including lectures and tutorials, are common approaches to information delivery, and these are favoured for ES. This works particularly well to establish a baseline of fundamental knowledge in the early years for planetary health and ES in healthcare. Recent research by Dixon *et al.*[23] provides evidence-based and subject-specific content statements that can be directly incorporated into teaching events. These statements were mapped to all curriculum subjects in dentistry, allowing educators from all disciplines to adopt these statements into their course material and teaching modalities. This approach should allow easy implementation by embedding short statements into existing lectures and allows frequent revisiting of the topic across all years of the programme. An incremental approach should embed the message that ES is a core part of oral healthcare delivery.

The proposed teaching methods for ES in clinical environments are less clear, with most

Table 3 Free-text responses to current or planned learning and teaching methods for ES in clinical environments

Learning and teaching method (clinical)	Number of responses
Still finalising delivery method/unsure/in discussion	5
Focus on high-quality oral healthcare delivery	3
Mentioned in clinical skills laboratory induction	1
Raising awareness on clinics	1
Opportunistic student initiatives	1
Problem-based learning	1
Using sustainable materials/instruments in clinic	1
Critique existing practices	1
Adopt digital workflows	1
Small group clinical teaching	1

Fig. 3 A bar chart demonstrating the frequency of reported barriers that complicate embedding ES in the undergraduate curriculum

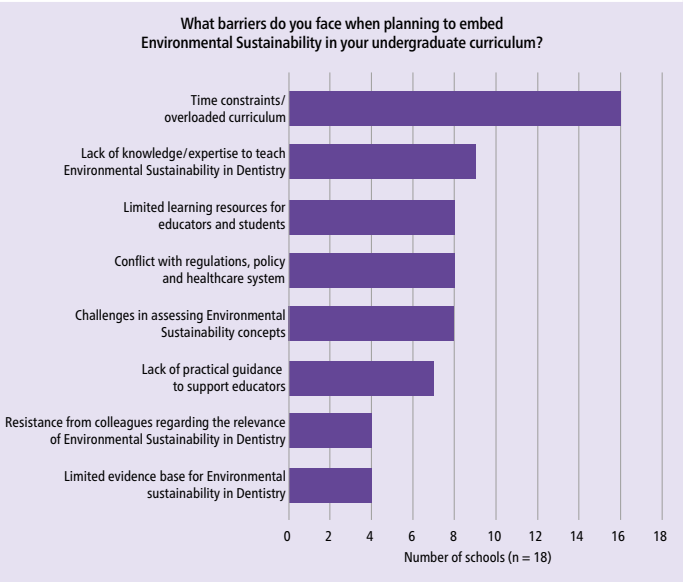

Fig. 4 A bar chart demonstrating the free-text responses to the drivers/facilitators that support the incorporation of ES in the undergraduate curriculum

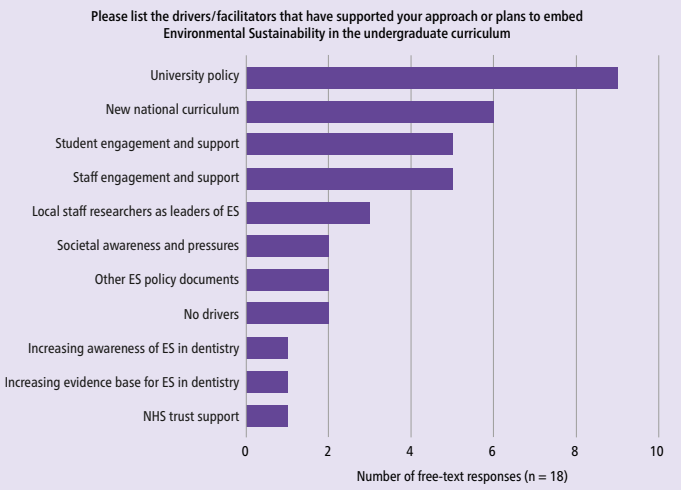

Table 4 Open-access resources and links

Open-access resources for environmental sustainability in dentistry and oral healthcare	Link
FDI World Dental Federation's MOOC	bit.ly/FDI-ES-MOOC
ADEE consensus report on learning outcomes and methods of teaching and assessment for environmental sustainability	bit.ly/ADEE-ES-LO
Evidence-based, subject-specific content statements for environmental sustainability	bit.ly/ES-CONTENT

responses demonstrating that schools are yet to finalise their planned approaches. In many respects, this imbalance is expected, as it is widely acknowledged that there are numerous barriers to delivering environmentally sustainable oral healthcare in the current climate.[4,24,25,26,27] While these undoubtedly complicate the delivery of environmentally sustainable oral healthcare, it is important to be aware that the environmental impacts of oral healthcare can be mitigated through the provision of high-quality oral healthcare.[11] Reducing the need to treat through preventive care, providing high-quality operative care that limits repairs and replacement, integrated care with smart structuring and organisation of patient care, and professional and patient ownership of care, all mitigate environmental impacts.[11,28] In addition to making an immediate impact to mitigate environmental impacts, educators and institutions have a role to develop the future workforce who should engage with stakeholders and challenge current unsustainable practices.[23]

Existing barriers that complicate embedding ES in the curriculum

The answer options for this question were developed from a comprehensive literature search of the health professional literature, but a free-text option was incorporated to allow full exploration of all barriers facing UK and Irish dental schools. The responses to this survey demonstrate that educators experience numerous barriers that complicate embedding ES in the curriculum. A lack of space and time in the curriculum is a widely reported issue in all health professional programmes and this complicates the incorporation of 'additional' ES content. It is argued that careful and strategic incorporation of ES into existing teaching events across all years of programmes will reduce the need to 'add' new events.[9] Although, good academic practice and governance should ensure that a curriculum remains valid and is sustainable through an approach of review and revision in a development cycle that should be in place to remove irrelevant and outdated components.

A lack of knowledge and expertise regarding ES and limited resources for educators and students were frequently reported barriers in this study. The availability of learning resources at all levels is increasing, namely with the FDI World Dental Federation's MOOC (bit.ly/FDI-ES-MOOC), ADEE's learning outcomes and methods of teaching and assessment (bit.ly/ADEE-ES-LO) and the recent evidence-based subject-specific content guidelines for ES (bit.ly/ES-CONTENT).[9,12,23] These are all available as open access and are designed to support educators and students at all levels (Table 4). It is envisaged that these core documents will promote ES and provide a platform for further development of additional resources.

Clinical regulations are acknowledged as a common barrier, particularly in relation to cross-infection control. Duane *et al.*[24] outlined many of these challenges in a critical review of the HTM 01-05 policy document. Strategies to teach ES in clinical environments were discussed above and additional methods were outlined in the ADEE consensus statement.[9]

The challenge of assessing ES is a common concern among academics. While assessment of environmentally sustainable behaviours in the provision of oral healthcare may be complex at present, assessment of student awareness, attitudes and knowledge should be achievable with existing methods. Multiple assessment methods have been recommended for ES in dentistry.[9] Similar to embedding content into existing teaching events, there are multiple opportunities to augment or modify existing assessment methods to incorporate ES, which may include awarding marks in an objective structured clinical examination, written papers, or within clinical grading.[23]

Existing drivers that support embedding ES in the curriculum

A positive finding is that universities are the most common driving force to support curriculum development. Increasingly, ES is forming a key part of university strategies and many institutions are demanding ES to be taught across all programmes. The recent publication of *The safe practitioner* framework by the UK national regulator of professional standards, the General Dental Council, is also a major driver for this change. Staff and student support for change has been recognised through previous surveys from across the world.[13,14,15,16]

Conclusion

Currently, ES is not taught in most dental schools in the UK and ROI. While the learning outcomes detailed in the General Dental Council's *The safe practitioner* framework will mandate this change, many schools face challenges in finalising the delivery modalities of ES teaching, particularly in clinical environments. Numerous barriers have been identified that complicate embedding ES in the curriculum, namely the overloaded curriculum and a lack of expertise and resources. Positively, universities, staff, students and the recently implemented learning outcomes are driving impactful change across the sector.

Ethics declaration

The authors declare no conflict of interest.

This study received ethical approval from the Dentistry Ethics Committee of the University of Sheffield (application number 056060). Informed consent was gained at the start of the survey through the provision of a participant information statement and consent form.

Data availability

The data supporting this study's findings are openly available in the University of Sheffield Research Data Repository at https://doi.org/10.15131/shef.data.26506234 under the terms of the Creative Commons Attribution (CC BY-NC 4.0) licence.

Author contributions

Conceptualisation: Jonathan Dixon, James Field, Nicolas Martin. Project design: Jonathan Dixon, James Field. Project execution: Jonathan Dixon, James Field, Nicolas Martin. Initial writing: Jonathan Dixon. Results and interpretation of data: Jonathan Dixon. Final writing and editing: Jonathan Dixon, James Field, Nicolas Martin.

Acknowledgements

The authors thank the UK Dental Schools Council for supporting this study with proactive dissemination of the survey among its member institutions. We express our sincerest gratitude to respondents for their active and willing participation to complete the survey for their own institutions.

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Chapter VI – Defining Learning Outcomes and Exploring Strategies to Embed Environmental Sustainability in Dental Education

Overview

The need to embed environmental sustainability (ES) in oral health professional (OHP) education has been established, and existing practices demonstrate significant support but limited action across the European continent. A definition of the intended learning outcomes for ES and proposals to teach and assess the topic are required. Overarching guidelines are required to make them applicable across various contexts; however, further insight from stakeholders regarding embedding this topic in an existing curriculum is also necessary.

The included peer-reviewed manuscript [326]:

> *Field J, Martin N, Duane B, Vital S, Mulligan S, Livny A, Lindberg P, Lundegren C, Long R, Lundbeck H, Ramasubbu D,* ***Dixon J****. Embedding environmental sustainability within oral health professional curricula—Recommendations for teaching and assessment of learning outcomes. European Journal of Dental Education. 2023;27(3):650–61.*

Presents consensus-agreed learning outcomes and methods of teaching and assessment for ES in OHP education. The learning outcomes were mapped to the existing Graduating European Dentist (GED) curriculum framework and, after review by the curriculum taskforce, were embedded into the online database (https://adee.org/graduating-european-dentist/graduating-european-dentist-curriculum).

Note: the research described in the 'Exploring Staff and Students Views on the Relevance and Opportunities for Environmental Sustainability in the Undergraduate Dental Curriculum' section below forms part of a publication that *is presented in Chapter VII*. Due

to journal requirements and the relationship between the two outputs, two studies were combined into a single publication. The publication is [327]:

> ***Dixon J**, Field J, Gibson E, Martin N. Curriculum Content for Environmental Sustainability in Dentistry. Journal of Dentistry. 2024 Apr 26;105021.*

This current chapter will consider the first part of this paper, 'Exploring Staff and Students Views on the Relevance and Opportunities for Environmental Sustainability in the Undergraduate Dental Curriculum'. This study used staff and student focus groups to explore opportunities to embed environmental sustainability in dentistry (ESD) within an existing curriculum. Staff and students were selected because they are the receivers and deliverers of the curriculum and, therefore, will provide key knowledge regarding existing teaching and assessment practices.

The included peer-reviewed manuscript [328];

> *Durnall O, Martin N, Mulligan S, **Dixon J**. Environmental sustainability: the attitudes and experiences of UK students in the oral health care profession. British Dental Journal. 2024.*

Presents the views of OHP students regarding the relevance of ES within the curriculum of dental schools in the United Kingdom (UK). A survey methodology was employed to uncover OHP students' awareness and level of concern regarding ES, as well as previous experiences of ES in the curriculum and proposed opportunities to embed ES within their programmes.

Candidate Contribution

The PhD candidate was the principal investigator for the 'Exploring Staff and Students Views on the Relevance and Opportunities for Environmental Sustainability in the Undergraduate Dental Curriculum' and conceptualised the design of the study, developed the research protocol, gained ethical approval and facilitated the focus groups. Additionally, the candidate provided the most significant contributions to project

implementation, data curation, analysis and write-up. The PhD candidate was the supervising author for the other two publications presented in this chapter. For these studies, the PhD candidate contributed to the study methodology and project execution but also provided guidance, supervision and leadership during data analysis and write-up.

Embedding Environmental Sustainability within Oral Health Professional Curricula—Recommendations for Teaching and Assessment of Learning Outcomes.

Introduction

This consensus document was developed by the 'Sustainability in Dentistry' special-interest group within the Association for Dental Education in Europe (ADEE). Previous research demonstrated a need to embed ES within the curriculum but also noted that limited guidance for educators is a significant barrier to real-world implementation[13,251,270]. As learning outcome-based education is widely accepted as best practice and is mostly adopted by European regulators and competent authorities, there was a need to develop learning outcomes and teaching and assessment methods for ES. This article presents consensus-based recommendations for these.

Methodology

An online special-interest group workshop was planned alongside the virtual ADEE conference in 2021. All registered attendees were asked to complete some preparatory work before the sessions. This work involved proposing new learning outcomes for ES and reviewing the GED curriculum to identify any existing outcomes that could be amended to include ES. In the live session, four breakout groups centred around the four domains of the GED curriculum allowed for more efficient work among delegates. The breakout groups collaborated to propose ES learning outcomes and teaching and assessment methods for each domain. The final proposals were discussed in the live session, and a core group of educators (authors) refined the documents to align with existing GED documentation.

Results

Thirty-one delegates from 12 countries attended the workshop and contributed to the consensus document. Seven new learning outcomes were proposed, and seven existing learning outcomes in the GED were modified to include ES. Teaching and assessment methods were proposed for each learning outcome based on the discussion in the online workshop. Six key themes stemmed from the discussions and were detailed in the paper:

i. Curriculum 'load' and ways to avoid further congestion of the curriculum
ii. Environmental Sustainability as a threshold concept and ways to improve understanding
iii. Adoption of new learning outcomes and the importance of constructive alignment
iv. Vertical and longitudinal integration of concepts
v. The use of case studies and student involvement to support delivery
vi. The use of novel and innovative methods to teach and assess Sustainable Dentistry

Relevance

This position paper is the first attempt to develop dedicated learning outcomes and teaching and assessment methods for ES. A consensus-based approach was used to achieve significant input from a wide range of educators from multiple countries. The learning outcomes serve as overarching statements of student capability upon graduation and should provide a focus for schools and educators who plan to embed this topic in the curriculum. The General Dental Council (GDC) in the UK adopted and modified two learning outcomes for their Safe Practitioner curriculum framework. All interventions presented in Chapter VIII are mapped to these learning outcomes.

Received: 12 April 2022 | Revised: 12 August 2022 | Accepted: 15 August 2022

DOI: 10.1111/eje.12852

COMMENTARY

WILEY

Embedding environmental sustainability within oral health professional curricula—Recommendations for teaching and assessment of learning outcomes

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Abstract

The FDI World Dental Federation suggests that "dentistry, as a profession, should integrate Sustainable Development Goals into daily practice and support a shift to a green economy in the pursuit of healthy lives and wellbeing for all, through all stages of life." This article reports on the recent activity of the Association for Dental Education in Europe Special Interest Group for Sustainability in Dentistry. Following on from the group's previous activities, which explored current educational practice, this work aimed to reach a pan-European consensus on a number of learning outcomes for environmental sustainability, in order to (i) support institutions in designing and delivering their curriculum, and (ii) to further harmonise the delivery of oral health professional education across Europe. This article presents specific learning outcomes relating to environmental sustainability and recommendations relating to curriculum development, including methods of teaching and assessment.

KEYWORDS
curriculum, dental, dental education, environment, sustainability

1 | BACKGROUND

The oral healthcare sector is not currently considered to be environmentally sustainable; it is a significant contributor to global greenhouse gas emissions, produces other pollutants, and generates unrecyclable waste.[1] In response to the impact of the wider healthcare sector on the environment, multiple national and international stakeholders have produced policy documents in response to the climate emergency. Such examples include the Paris Agreement,[2] the United Nations Sustainable Development Goals,[3] WHO COP reports[4] and NHS England's Delivering a "Net Zero" National Health Service Policy.[5] More recently, there are examples of dental-specific policy documents, such as the Joint Stakeholder Statement for Consensus on Environmentally Sustainable Oral Healthcare.[6] Here, the FDI recognises the importance of collaborating with all stakeholders in the interests of sustainability—and recommends that dentistry, as a profession, should integrate Sustainable Development Goals (SDGs) into daily practice and support a shift to a green economy.

It is clear that in order to achieve these goals, Environmental Sustainability (ES) must be formally integrated into curricula for Oral Health Professionals (OHPs). In 2019, during the annual meeting of the Association for Dental Education in Europe (ADEE), a Special Interest Group (SIG) reported a consensus view regarding the

importance of ES in dental education, and raised awareness of the fact that academics need support in developing curricula relating to ES. A clear need was established for the creation of teaching materials and guidance for educators and those responsible for curriculum development.[7] Aligning with other ADEE SIG recommendations,[8] the group suggests that learning outcomes, teaching activities and assessment activities should be developed and shared collaboratively. As such, to support educators and to further harmonise the delivery of OHP education across Europe, more formal curriculum elements relating to ES need to be created. This aspiration complements recommendations from the Graduating European Dentist (GED) curriculum task force,[9] which encourage subject matter experts to collaborate and develop discipline-level learning-outcome-based curricula.

Alongside the work of this ADEE SIG, other educational networks are also beginning to report scoping activity within their member institutions. A scoping review by Martin et al.[10] found that "the lack of public and professional awareness is the greatest driver to engage with a positive change of behaviour and attitudes. Awareness through education is key at all levels and this should be the bedrock of future strategies." In 2021, Joury et al reported a cross-sectional survey between dental schools in the UK (QMUL) and the USA (Harvard) which concluded that neither school formally taught ES—and major barriers included a lack of understanding and a lack of educational strategy and material. The paper called for training courses and materials for educators.[11] Meanwhile, Gershberg et al. carried out a cross-sectional survey among students at dental schools across the USA to assess their experiences and training in relation to sustainable dentistry.[12] Despite a low response rate (5%, $n = 378$) the data showed that a large majority of students felt that ES in dentistry was important, and yet around 75% of respondents felt poorly educated in this area. Importantly, the students made suggestions for incorporating ES into coursework relating to infection control, practice management and dental public health.

Within the wider discipline of medicine, there has been a similar (albeit more advanced) direction of travel. An Association for Medical Education in Europe consensus statement on planetary health and education for sustainable healthcare[13] recognised that inclusion of climate change in medical curricula in most countries was low (only 15%). Furthermore, the document proposes a number of applicable learning outcomes across a variety of domains that could be included within the curriculum, developed through a Delphi approach involving UK medical educators.[14] Later studies that employed the Delphi inquiry methodology have also been reported, proposing learning outcomes involving input from medical educators in wider networks including the US, India, Australia and Canada.[15] What is needed, however, to facilitate implementation at the institutional level is some guidance regarding *how* these outcomes could be taught, reinforced and observed/assessed within any given professional context.

Therefore, the aims of this consensus article from the ADEE SIG are to:

- report European consensus on suggested learning outcomes for ES in relation to the GED curriculum
- provide recommendations for teaching ES within existing OHP programmes.

2 | METHODS

The consensus was developed using a model similar to that described by Field et al.[8] This consisted of three methodological components, in keeping with Kern's model of curriculum development[16]:

(i) an initial needs analysis (involving a scoping questionnaire and a SIG discussion),
(ii) setting educational goals and objectives (consisting of a separate SIG discussion with pan-European educators to define specific learning outcomes) and, at the same time,
(iii) developing educational strategies (to include methods of teaching and assessment).

The scoping questionnaire and initial SIG discussion are reported in the first paper by the group.[7] This activity took place during the ADEE 2019 Annual Conference in Berlin. Unfortunately, due to the impact of the COVID-19 pandemic, the next annual conference (Strasbourg 2020) was postponed by a year. As such, the SIG activity resumed in time for the ADEE 2021 Annual Conference, which was held online.

2.1 | Session format

Delegates who were responsible for curriculum development in their respective schools, or who led existing elements relating to ES, were invited to attend the SIG workshop. The workshop was planned to run online using Zoom, a cloud-based collaborative videoconference platform (Zoom Video Communications Inc. 2021), chaired by the two SIG leads (JF and BD). Four breakout groups were planned (representing the 4 GED domains) and, as such, two extra facilitators were identified from the team involved in the initial paper (JD, DR). The 4 GED domains comprise (I) Professionalism, (II) Safe and Effective Clinical Practice, (III) Patient-centred Care and (IV) Dentistry in Society.

2.2 | Preparatory work for delegates

Delegates were allocated into one of the 4 breakout groups by the conference organisers to ensure reasonable representation from each geographical area and language across all groups. A week before the session, delegates were sent an email informing them of which domain they had been attributed to, along with the following documents:

- A copy of the relevant GED curriculum domain explaining and listing the existing learning outcomes
- A guide to writing and using learning outcomes
- A copy of the SIGs first paper[7]
- An infographic showing a range of verbs associated with each level of Bloom's taxonomy[17]
- A blank template for formulating some proposed learning outcomes for the relevant GED domain

The template was designed in such a way that it would facilitate constructive alignment[18] by sequentially asking:

(i) What do you intend the students to be able to do?
(ii) What is the best verb to describe this activity?
(iii) How could this be taught or reinforced?
(iv) How could this be assessed or observed?

Delegates were also encouraged to consider the existing GED learning outcomes within their domain, and whether any of these already covered aspects of ES, or whether they could be modified in some way to do so.

2.3 | The live session

The live session was online and used the Zoom video conferencing software (Zoom 2021). Delegates were made aware that the session was going to be recorded and the Zoom platform reminded delegates that this was happening and asked for the participants' consent. Without consent, it was not possible to continue with the session. The purpose of the recording was discussed in the introduction to the session—the primary purpose being that of making the session available to conference delegates at a later date. The session consisted of a brief introduction by the session chairs, which included a breakdown of the SIG activity to date. Time was spent explaining the rationale behind the workshop including discussion around how learning outcomes should be formulated. Delegates were then automatically transferred into their respective breakout rooms by the Zoom hosts (ADEE administrators). Each domain facilitator mediated a 45-min discussion around potential learning outcomes with their delegates, whilst keeping notes. The groups then re-joined the main meeting for summary discussions relating to each GED domain, before a general summary discussion at the end which included the next steps in the project.

3 | RESULTS

A total of 31 delegates, representing 12 different countries, attended the SIG workshop. Delegates were split as evenly as possible across each of the 4 GED domain breakout groups. Following discussion within the breakout groups, a number of suitable learning outcomes and methods of teaching and assessment were devised for each of the 4 GED domains.

Following the live event, a core group continued to work on reformatting the intended learning outcomes to include information relating to:

(i) the particular GED domain that each referred to
(ii) whether the learning outcome was new or a modification of an existing learning outcome
(iii) specifically, what educators were wanting students to be able to do
(iv) how this could be taught or reinforced
(v) how this could be assessed or observed
(vi) the written learning outcome itself

The ES learning outcomes relating to the current GED domains are represented in Tables 1–4. The tables are created so that educators can see the applied methodology of constructive alignment—and the resultant learning outcomes are labelled as either "new" (if they are additional to existing GED learning outcomes) or "modified" (if they result from amendment of existing GED learning outcomes).

During the live event, the group had a significant discussion about implementation strategies following the breakout groups. These discussions included the themes below and informed the development of the learning outcomes. They are each considered in the discussion:

- Curriculum "load" and ways to avoid further congestion of the curriculum
- Environmental sustainability as a threshold concept and ways to improve understanding
- Adoption of new learning outcomes and the importance of constructive alignment
- Vertical and longitudinal integration of concepts
- The use of case studies and student involvement to support delivery
- The use of novel and innovative methods to teach and assess sustainable dentistry

4 | DISCUSSION

The discussion considers each of the themes emerging from the breakout groups, in turn.

4.1 | Curriculum "load" and ways to avoid further congesting the curriculum

It has long been acknowledged that the overloaded curriculum presents a common challenge for OHP education providers.[19,20] A clear need has now been established to teach ES within OHP curricula,

TABLE 1 Proposed learning outcomes for GED relating to environmental sustainability domain: Domain 1—Professionalism

Sub-domain? New or modified?	What do you intend the students to be able to do?	What are the best verbs to describe this?	How could it be taught or reinforced?	How could it be assessed or observed?
Ethics New	Be aware of the ethical principles relating to sustainable dentistry	List Explain Discuss Apply	• Principles can be introduced using the infographic (ref) • Principles can be reinforced through case discussions and group reflections • Reinforced at key learning events/opportunities across all programmes • Exposure longitudinally throughout a programme • Teachers can be encouraged to use and make reference various infographics to reinforce the principles as part of their teaching (see paper and also https://www.fdiworlddental.org/sustainability-dentistry)	• Students can be asked to list and explain the principles, and their potential application, by written examination • Students can be presented within a scenario (written or practical) and asked to identify/correct current practices, or discuss the impact on the environment • Students can be asked to discuss or describe one change they would make to their current practices to improve sustainability • Students can be asked to reflect on their own, or observed practice in relation to sustainability • Students can be asked to consider sustainability when developing personal development, or action plans
	• Discuss the main principles relating to sustainable oral healthcare • Explain the importance of practising sustainable oral healthcare • Discuss the challenges/barriers to implementing a sustainable approach to oral healthcare • Discuss how the ethical principles of sustainable dentistry can be applied to [present a scenario]			
Regulation Modify 1.2.5	Be aware of the sustainable development goals and current legislation relating to sustainability	Explain Discuss Comply	• A dedicated learning event(s) to introduce the background and potential impact of meeting SDGs, including any relevant legislation	• Students can be asked to research the SDGs and present a summary of how they might impact on dentistry, particularly in relation to use of personal protective equipment (PPE) and digital dentistry (material use, and travel)
	• Discuss the implications of, and be able to comply with, general legislation or regulation in areas such as health and safety legislation, infection prevention and control procedures, data protection, the use of ionising radiation *and sustainability*			
Professional behaviour New	Encourage and promote sustainable approaches within the workplace	Demonstrate	• Tacit learning, by observing teachers or clinicians • Clinical group discussion using a case-based approach • Explicit discussion within the clinical skills learning environment about materials use and environmental impact • Discussion around various lifecycle or impact models • Dissemination and championing of the 8 domains of sustainability across teaching events • Encouraging peers and the wider team to work sustainably	• Students can be assessed in the clinical or clinical skills lab environment (perhaps as part of an overall professionalism grading, or an independent grade as part of an OSCE) • Students can be asked how they would support specific SDGs or local sustainability policies as part of a written exam, or an oral exam • Students can be asked to generate explicit action plans within their academic or clinical environments to support sustainable working
	• Demonstrate a respectful approach to the environment during clinical practice • Critique current clinical practices in relation to environmental impact, and suggest realistic and practical solutions			

but this raises issues in terms of adding further content and the use of additional resources. Simply adding a standalone course for ES will be impossible in most contexts. Additionally, delivering an individual stand-alone course at one point in the curriculum prevents the important integration and longitudinal development of threshold concepts into the programme. Longitudinal integration of ES is considered essential to enable the inclusion of increasing levels of subject complexity as the student progresses. Facilitating this process

TABLE 2 Proposed learning outcomes for GED relating to environmental sustainability domain: Domain 2—Safe and effective clinical practice

Sub-domain? New or modified?	What do you intend the students to be able to do?	What are the best verbs to describe this?	How could it be taught or reinforced?	How could it be assessed or observed?
Team working and communication Modified 2.3.14	Consider environmental impacts (benefits and harm) when offering advice, devising treatment plans, or setting recall intervals for patients	Establish Consider Demonstrate	• Principles can be reinforced through case discussions and group reflections • Reinforced at key learning events/ opportunities across all programmes • Tacit learning, by observing others (peers, or staff) • Explicit discussion within the skills learning environment about materials use and environmental impact	• Students can be assessed in the clinical or skills lab environment (perhaps as part of an overall professionalism grading) • Students can be presented within a scenario (written or practical) and asked to develop a treatment plan whilst discussing the impact on the environment
	• Evaluate the results of treatment and establish an effective *and environmentally sustainable* monitoring and maintenance programme for patients, in cooperation with the wider dental team where appropriate			
Team working and communication Modified 2.4.3	Communicate environmental impacts to the wider dental team and patients, taking steps to minimise these wherever possible	Communicate Manage	• Tacit learning, by observing teachers or clinicians communicating with the team and with patients • A dedicated learning event(s) for the whole dental team, such as a symposium • Inclusion of sustainability within clinical checklists • Clinical group discussion using a case-based approach • Raising awareness of prices of materials, lifecycle analysis and disposal costs	• Students can be assessed in the clinical or skills lab environment (perhaps as part of an overall professionalism grading) • Students can be asked to discuss or describe one change they would make to their current practices to improve sustainability • Students can be assessed communicating with the team, or with patients, as part of an OSCE assessment • Students can be asked to design infographics or create patient resources • Students can be asked to role play discussions with patients and the dental team about environmental impacts

	• Effectively communicate and manage the hazards within the clinical environment including:
	  • cross-infection control
	  • hazardous materials
	  • *packing, procurement and use of resources*
	  • *impact on the environment*
	  • working with ionising radiation			

TABLE 2 (Continued)

Sub-domain? New or modified?	What do you intend the students to be able to do?	What are the best verbs to describe this?	How could it be taught or reinforced?	How could it be assessed or observed?
Evidence-based practice Modified 2.1.3	Evaluate advertisements and claims made by industry so that products, materials and techniques are chosen that minimise environmental impact	Evaluate Critically appraise	• Mediated discussions around real advertisements and claims • Integrating discussions about sustainability into existing critical appraisal sessions • Encouraging sympathetic engagement with industrial partners to discuss environmental impact	• Students can be assessed through case-based discussions or as part of written assessments • Students can be asked to reflect on material/ equipment choice
	• Evaluate the validity of claims made by industry, primarily in relation to the *clinical and environmental* risks, benefits and cost of products and techniques			
Management and leadership Remain unchanged 2.2.6 Modified 2.2.3	Identify areas of concern with current practice, and implement positive change	Identify Implement Manage Plan Integrate	• Tacit learning, by observing teachers or clinicians communicating with the team and with patients • A dedicated learning event(s) for the whole dental team, such as a Symposium • Clinical group discussion using a case-based approach • Elective projects	• Students can be assessed through case-based discussions or as part of written assessments • Students can be asked to reflect on material/ equipment choice • Students can be asked to discuss or describe one change they would make to their current practices to improve sustainability • Students can be assessed communicating with the team, or with patients, as part of an OSCE assessment • Students can be asked to reflect on their current practice within a longitudinal portfolio of practice • Students can be asked to make video diaries to highlight concerns

	• Consider implementing changes within the team and the wider practise environment that will significantly improve efficiency and sustainability of resources
	• Effectively integrate other members of the dental team regarding risk management, for example:
	  • working posture
	  • visual perception
	  • the use of equipment
	  • dealing with stress and burn-out
	  • cross-infection control
	  • working with hazardous chemicals and ionising radiation
	  • environmental sustainability			

(Continues)

TABLE 2 (Continued)

Sub-domain? New or modified?	What do you intend the students to be able to do?	What are the best verbs to describe this?	How could it be taught or reinforced?	How could it be assessed or observed?
Professional education and training Remain unchanged 2.5.1	Be aware of the environmental impact (benefit/harm) of new technology and, where possible, apply the latest technology to reduce the need for material use, patient travel, and to improve efficiencies around patient triage and assessment	Describe Discuss Apply	• Mediated discussions around published papers relating to tele-dentistry • Laboratory and clinical sessions to introduce digital workflows	• Students can be asked about technologies in written assessments • Students can be asked to critically appraise papers relating to remote consultations • Students can be asked to obtain digital records in the skills lab or on the clinic
	• Use contemporary information technology for documentation, continuing education, communication, management of information and applications related to healthcare			
Audit and risk management Remain unchanged 2.4.7	Be aware of any relevant sustainability policies (local or regulatory) and use these to audit current practice	Audit Interpret Plan	• A dedicated learning event(s) for the whole dental team, such as a symposium where audit results are discussed • Group discussion of policy and plans to implement or audit	• Students can be asked to carry out an audit e.g., waste use • Students can be asked to plan interventions based on the results on an audit
	• Interpret, implement and disseminate aspects of audit and clinical governance			

means that ES is more likely to be embedded within the graduating dentist's practices, and they are more likely to implement sustainable solutions and act as advocates for change in the profession.

It is not anticipated, nor feasible, that higher education institutions will completely change their curricula to incorporate ES. However, a curriculum review process, perhaps including curriculum mapping, can allow educators to establish an overview of the current curriculum and to identify any areas where ES could be incorporated, across the whole length of educational programmes. The commonly accepted student-centred approach to curricula, which focuses on and aligns resources to support students in developing fundamental, lifelong knowledge, skills and attitudes, may present more opportunities for educators to embed ES within their curriculum.[21,22]

4.2 | Environmental sustainability as a threshold concept and ways to improve understanding

A threshold concept is defined within the European OHP Education Glossary, Articulate,[23] as "A topic within a curriculum that, when understood, results in fundamental changes in perception and practice of other parts of the subject/discipline." In many ways, introducing and teaching ES is similar in scope to other topics such as Professionalism or Inter-Professional Education. In this regard, it is not sufficient to simply augment existing curricula with additional learning events, and learning outcomes, relating to ES. Instead, there needs to be a school or institutional-wide strategic approach. Gaining a basic understanding has been identified as a strategic need—both in the papers discussed above and also during the work with this SIG. Teaching materials and resources that allow staff and students to develop a basic and common understanding of ES should be introduced first—and then over time, this can be built on to include other learning and assessment strategies. The suggestion from the group is that as a threshold concept, ES should be considered in everything that is delivered as part of an OHP programme—and some educators discussed the concept of a "virtual course or topic" that spans the whole curriculum. Whilst there are few learning events or materials dedicated specifically to the topic of ES, the aim is to embed sustainable approaches into the rest of the curriculum.

4.3 | Adopting new learning outcomes and the importance of constructive alignment

Constructive alignment is defined within the Articulate glossary[23] as "The design of learning activities and assessment tasks to support the intended learning outcomes of a programme." One of the aims of this SIG was to determine ways in which learning outcomes relating to ES can be taught and assessed within the curriculum. As such, the group is aligning with this approach. Educators can utilise the suggestions provided in Tables 1–4 to construct their curricula carefully—either by working backwards from the intended assessment methods, to decide the best way to deliver the learning material—or by beginning with the teaching methods and then constructing assessments based on the original learning outcomes. Either way, this process avoids the pitfall of introducing learning outcomes, without ever introducing relevant and aligned teaching or assessment activities.

TABLE 3 Proposed learning outcomes for GED relating to environmental sustainability domain: Domain 3—Patient centred care

Sub-domain? New or modified?	What do you intend the students to be able to do?	What are the best verbs to describe this?	How could it be taught or reinforced?	How could it be assessed or observed?
Scientific basis (3.1) New	Recall the evidence base surrounding sustainable approaches to dentistry, and rationalise the methods used to determine the environmental impact of materials and methods	Describe Explain Apply	• Case-based discussion, incorporating cases of a variety of patients, all with different dental histories and oral health needs. Raise awareness of environmental impact of oral healthcare delivery for these different patient groups. • Videos, blogs and podcasts from key stakeholders • Online resources to test and orient the cohort such as SuliTest	• Short answer vignettes • Written reflective reports • Reflective portfolio entries after clinical encounter • Life cycle analyses
	• Apply the scientific knowledge base in relation to the environmental impacts of common treatment methods, and common approaches to the delivery of care • List the main elements of the life-cycle analysis (LCA) process			

Treatment planning (3.3)
New
	Make informed decisions based on how their choice of treatment or the delivery of care can impact more widely on the environment	Apply
		Explain
		Demonstrate
			• The use of infographics to demonstrate the environmental impacts of
			  • Importance of planning treatment (including number of appointments)
			  • Repeat or multiple visits
			  • A shift to remote consultation
			  • Antibiotic use
			  • Effective prevention and the need for less intervention
			  • Single use items
			• Case-based discussion
			• Videos, blogs and podcasts from key stakeholders
				• Clinical gradings for treatment planning
				• Case based discussions
				• OSLER

	• Rationalise patient-centred approaches to oral health, that are consistent with maintaining environmental and planetary health			
Establishing and maintaining oral health (3.4) New	Work efficiently and effectively to promote prevention and reduce the need for further oral healthcare intervention in their patient base	Demonstrate Deliver Develop	• Treatment planning and forecasting of the delivery of care (projected treatment plans indicating visits needed, time allocation, material use, etc.) • Case-based discussion • Impact case studies	• As an explicit component of case presentations or written reflective reports • Clinical gradings for treatment planning • Case-based discussion • OSLER
	• Develop effective patient-specific strategies for preventive oral health, reducing the need for recall, operative intervention and material use			

4.4 | Vertical and longitudinal integration of concepts

Whilst it is recommended that the concept of ES should incorporate across the breadth of the curriculum, what does this mean in practice? The suggestion is that ES is incorporated both vertically (integration between the clinical and basic science stages of the curriculum) and horizontally (integrating across subjects in any given year, and across programmes). In essence, the key to curriculum integration is the need to address the learners' knowledge gaps:

- *What is ES?*—Creating awareness through exploration of the environmental impacts of the provision of oral healthcare and normalising the concept at a local level.
- *What can I do?*—Identification of specific actions that can be achieved at an individual level and as part of the larger "oral healthcare industry and associated supply chain" by working collaboratively across all sectors.
- *How can I do it?*—Understanding that the main aspect of the work provided by an OHP is associated with preventable diseases and as such this is where the greatest environmental

TABLE 4 Proposed learning outcomes for GED relating to environmental sustainability domain: Domain 4—Dentistry in society [Correction added on 19 May 2023 after first online publication: the text "Daily Affected Life Years" have been updated to "Disability Adjusted Life Years" in this version.]

Sub-domain? New or modified?	What do you intend the students to be able to do?	What are the best verbs to describe this?	How could it be taught or reinforced?	How could it be assessed or observed?
Health promotion and disease prevention 4.2.4 Modified	Advocate for improving population health in general, through public health initiatives, recognising that less individual treatment need is required—and to discuss the potential beneficial impact that this might have on the use of materials and resources and the environment	Discuss Describe Explain Rationalise	• Impact case studies demonstrating the impact on population need, treatment cost, material use and the environment, for various types of public health initiative • Root cause analyses to help students to rationalise cause and effect • Embedded within the Dental Public Health aspects of programmes • Outreach events or symposia with relevant student groups or societies • Introduce the concept of health harm (e.g., in Disability Adjusted Life Years) for different healthcare interventions • Identify the common values between sustainable development and health promotion such as individual and collective responsibility, respect for others and solidarity, participation of people in decisions that affect them, social justice • Identify the common collective levers for change: advocacy, social commitment, legislative and budgetary measures, organisational changes and individual levers: changes in knowledge, attitudes and individual skills	• Creation of short podcasts or videos • Accounts of reflective practice based on observations within the clinical environment or engagement with wider events relating to ESD • Written case-based scenarios
	• Discuss the importance of behaviour change at a population level, particularly in relation to overall population treatment need, the use of resources and the environment			
Healthcare systems 4.4.4 Modified	Students should be aware of their role, as an oral healthcare professional, in contributing to sustainable development goals. They should be able to describe how the systems within which they will work, can affect these goals	Discuss Describe Explain Rationalise	• Demonstration of remote consultation • Community practice placements • Working with digital workflows, mindful of contrasting material use, potential for error and time • Small group tutorials around SDGs, consider ways dentistry can contribute to these • Discussion around different healthcare system models and potential challenges each possess in relation to ES	• Team-based projects with other OHPs within the school to report how the team can contribute to SDGs • Written papers to assess knowledge of mechanisms of sustainable healthcare delivery • Community practice placements and associated reflections • Competence with using digital workflows for providing patient care, or in the skills lab
	• Discuss the importance of oral health professionals in contributing towards environmental Sustainable Development Goals (SDGs) • Describe the various mechanisms of delivering healthcare, including strategies that improve accessibility and sustainability such as remote consultations, digital workflows and domiciliary/community visits			

impacts are to be gained. A key message is that ES has desirable impacts that reach well beyond the environment; it is good for the patient with whole person-centred healthcare benefits, good for society, good for the profession and good for the wider economy.

Initially, this group suggests a greater emphasis is needed on understanding the fundamental principles of ES in the earlier preclinical years for any healthcare course. As students progress, it is possible to build on these early principles, and introduce new ways of appraising the ES of systems, and how this relates to dental

practice. These models can be revisited and strengthened in future years, becoming increasingly complex and involving more disciplines and areas as time goes by. This model provides an opportunity for the synergistic integration of ES concepts alongside the delivery of good oral healthcare, which must remain the bedrock of all curricula. Initially, as students begin to learn about general medical problems and medicine relevant to dentistry, relevant aspects such as sustainability of patient consultation and travel, or sustainability of prescribing and medication use, can be introduced. As students prepare to move into a clinical environment, ES could be incorporated as a part of key areas such as (but not exclusively) patient care planning, preventive dentistry and decontamination. Beyond the integration of source reduction, there are many opportunities for further integration with core subjects such as public health screening programmes, service delivery models and the co-creation of patient information. The concepts of horizontal and vertical integration are further discussed by Hays.[24] Over time, as the relatively new concept of ES in clinical dentistry evolves, curriculum leads will need to regularly review content and practice to ensure that taught approaches remain valid—examples of suggestions for informing curriculum review include the disciplines of Endodontics[1] and Restorative Dentistry.[25]

4.5 | The use of case studies and student involvement to support delivery

Case-based learning (CBL) has proven to be an effective teaching method in healthcare education[26,27] and this approach is used widely across the profession. As such, OHP students are already often familiar with this method of learning. CBL, by promoting students' critical thinking and decision-making, is a valuable method of choice for developing students' opinions and values in relation to ES. Clinical cases provide real context, and ES is gently encouraged as a normal consideration—eventually becoming part of the range of expected professional attitudes. Some simple examples of fundamental decision-making processes include repairing defective restorations instead of replacing them, and choosing from a range of suitable materials based on factors such as packaging, subsequent waste and procurement journey. Table 5 outlines a case example by which the concept of "source reduction" is explored as the main waste management route to ES[28]—and how its construct is useful as a tool for systematically teaching and reinforcing a sustainable approach to treatment.

In addition to clinical or "dental" case studies, general case studies relating to ES can allow educators to introduce, and students to explore, the key characteristics and implications of particular decisions and interventions. Concrete and contextual ES issues, such as travel issues, waste and energy utilisation can be discussed in order to provide new insights and propose practical solutions to resolve the problems. These "cases" should be co-created with students—but also shared across our educator network as a general resource. Additionally, this will serve as an opportunity for Inter-Professional Education with students from a variety of disciplines (healthcare and beyond). In the same way, students should be encouraged to be "advocates of change"—OHPs who are empowered to drive change—and initiatives that are taken forwards should be shared within the teaching community. Most OHP students are younger professionals, with relatively long careers ahead—and in this regard, they will undoubtedly face impact from environmental pressures that is far more longstanding than their teachers will—at least from a professional perspective. Their interest in changing the existing status of how dentistry and the environment affect each other is therefore very clear, and they could serve as major change agents; our current students are the future. Student-driven (or "student-centred") learning is a well-established concept, which is already shown to give more satisfactory and meaningful learning experiences.[30,31] Examples of students' active involvement in change could include identifying "hotspots" and priority areas to focus on—either in direct liaison with curriculum committees within the school—or as part of their students' society agenda.

TABLE 5 Case study: Source reduction and waste management

Here, the concept of "source reduction" is explored as the main waste management route to ES.[28] At the point of delivery of care, reduction is achieved through the provision of high-quality oral healthcare by engaging with good practice, embodied in four domains (below)[29]:

- *Preventive care*—The assessment and management of systemic and local risk factors with a practical and patient-centred preventive regime.
- *Operative care*—The combination of core knowledge, skill sets, experiential learning and teamwork acting synergistically. The provision of high-quality operative interventions results in durable treatment that will require fewer repairs and replacements.
- *Integrated care*—The integration of services, patient-centred structured treatments and patient participation as co-creators and co-managers of their care.
- *Ownership of care*—Active participation in core and complementary activities that leads to professional development, a passion to excel and the satisfaction of achievement.

The outcome of this integrated approach for the delivery of oral care is two-fold:

- Fewer appointments, with fewer patient journeys and reduced need for professional interventions, results in an overall reduction in CO_2 emissions
- Increased longevity of restorations and a reduced need for procurement, which results in an overall reduction in waste generated.

This construct provides a perfect starting point for the integration of ES into the current curriculum, without the need for separate or independent stand-alone courses. It shows how, through the promotion and implementation of a framework for the management of preventable diseases, we attain good oral health and positive environmentally sustainable outcomes by way of a reduction in CO_2 emissions, waste and pollution.

4.6 | The use of novel and innovative methods to teach and assess sustainable dentistry

Some of the activities proposed in Tables 1–4 represent a socio-constructive paradigm, where students co-construct their knowledge in a social context within an active learning framework. Active

learning is student-centred, can be challenge-based and collaborative, and is preferably situated in authentic contexts relating to contemporary challenges. Typical activities can include the use of case studies as described above, but we also propose creating other activities where students are forced to actively consider and reflect on context. For example, activities may be designed that allow students to reach out and engage with wider society, and feel a potential immediate impact—these will act as powerful learning experiences. Such learning activities can be designed collaboratively with stakeholders external to the university, or by critically analysing common or frequent societal actions such as the recommendation and selection of oral hygiene products, or by drawing attention to types of packaging or place of manufacture, in relation to ES. With regards to designing learning activities in general, any type of learning activities that students find engaging are likely to be welcomed—and are likely to have more impact—and therefore, educators should consider engaging students with ES concepts through quizzes, flipped learning and reflections on clinical observations. This can be built on further, to develop concrete problem-solving exercises involving more complex cases and collaborative efforts and interactions with society.

Several of the strategies discussed in this article can also be tied together in innovative ways, such as asking the students to keep a reflective portfolio, with elements that relate specifically to sustainable practice—and encourage reflection across a number of activity domains—including areas of competence such as communication skills, collaboration skills, leadership skills, theoretical knowledge, professionalism and an evidence-based approach to practice. Students can be asked to create their own contextual and meaningful links across various facets of OHP education that are relevant to the cases they are involved with—for instance, one such example is where students may identify the significance of how individual patients' travel plans and habits could be linked to care planning.

Of course, assessments that are designed to determine whether students can meet certain learning outcomes, do not always need to be confined to simple question and response arrangements. Co-creation of resources—both between student colleagues and with teaching staff, means that student involvement in the exercise can be assessed, as can the quality of any potential outputs. In this way, resources that are created may be valuable in raising awareness in the wider society—asking students to create materials such as podcasts, or infographics, or considering how they might communicate using social media, all provide excellent opportunities to engage and enthuse students, whilst potentially benefitting wider society. That said, it is possible to build simpler forms of ES assessments into the current curriculum in the first instance. Assessment criteria regarding ES can often be included without major change to the method of assessment. For instance, ES can be added as a mandatory criterion for master thesis writing, or as part of regular clinical skills assessment (e.g., in relation to hygiene routines, prevention perspectives, treatment choices, individualised person-centred care plans, holistic care, treatment planning, appointment scheduling, environmental influences, travel requirements and taking responsibility for a lifelong perspective on treatment choice).

4.7 | Incorporating the learning outcomes into the Graduating European Dentist (GED) curriculum

Open access publication of the original GED curriculum within the European Journal of Dental Education ensured that the original curriculum content, and associated guidance, was accessible to all. Within the spirit of consensus and accessibility, the decision was taken by the GED Taskforce, to evolve GED beyond a series of static documents—and to create an active and dynamic resource for educators and students. As such, the GED suite of documents is accessible through the ADEE website here. ADEE encourages individuals, institutions, educators and industrial partners to leave comments and suggestions on the various domains and learning outcomes—and these are revisited periodically by the GED taskforce. An ADEE-approved French translation of the curriculum is available here. Following the publication of this article, the suggested learning outcomes for sustainability will now be proposed to the GED task force for incorporation into the live online GED curriculum.

5 | CONCLUSIONS/RECOMMENDATIONS

It is clear that in order to meet national and global net-zero pledges and to effectively implement the SDGs into current dental practice, ES must be formally integrated into curricula for OHPs. The SIG established that simply defining ES learning outcomes for educators was not enough. Instead, the group has worked together to reach consensus not only on learning outcomes, but methods in which these can be robustly embedded, taught and assessed within the modern dental curriculum.

The SIG makes the following recommendations for consideration when integrating learning outcomes for ES:

- The integration of learning outcomes should be planned logically and reinforced longitudinally throughout the programme.
- Institutions and educators should encourage and empower students to be ES advocates of the present and future to drive sustainable change.
- Educators should co-create resources with students, inviting student opinion about how they might wish to express their understanding, opinion and motivation for engaging with ES initiatives in dentistry.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Julian Fisher and Professor Jan Clarkson for their views on the orientation of this commentary.

CONFLICT OF INTEREST

At the time of writing, James Field, Nicolas Martin and Steve Mulligan were acting in a consultant capacity for GSK Consumer Healthcare specifically with regard to sustainability.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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[Correction added on 3 March 2023 after first online publication: Reference citation and reference for Brynhildsen et al have been updated in this version]

How to cite this article: Field J, Martin N, Duane B, et al. Embedding environmental sustainability within oral health professional curricula—Recommendations for teaching and assessment of learning outcomes. *Eur J Dent Educ*. 2023;27:650-661. doi: 10.1111/eje.12852

Exploring Staff and Students Views on the Relevance and Opportunities for Environmental Sustainability in the Undergraduate Dental Curriculum

Due to journal regulations, two studies were combined into one published manuscript. The text below describes the first piece of research titled *'Exploring Staff and Students Views on the Relevance and Opportunities for Environmental Sustainability in the Undergraduate Dental Curriculum*'. The peer-reviewed manuscript for this study is included in Chapter VII and is titled 'Curriculum Content for Environmental Sustainability in Dentistry'.

Introduction

Whilst the need to embed ES in undergraduate OHP education has been established and consensus-agreed learning outcomes and teaching and assessment methods have been published, more practical guidance on how to embed ES into an existing curriculum needs to be developed. Dental curricula are typically highly complex and overloaded with content; research is required to identify opportunities to embed ES within the existing teaching and assessment processes. Including stakeholders in any curriculum development project is essential; the curriculum's deliverers (staff) and receivers (students) may provide critical insight into any potential strategies.

Aims and Objectives

This study aimed to: identify suitable strategies and opportunities to embed ES within an existing curriculum through a series of focus groups with OHP students and academic staff.

This study has two objectives:

- To uncover staff and student opinions on the clarity and importance of selected ES learning outcomes.

- To explore academic staff's and students' opinions on strategies to teach and assess selected ES learning outcomes within undergraduate OHP curricula.

Methodology

Staff and student focus groups were used to explore the views of staff and students regarding ES in dental and OHP education. Prior to commencing the research, ethical approval was granted by the Dentistry Ethics Committee at the School of Clinical Dentistry, University of Sheffield (application number 056582).

Recruitment

All students enrolled in undergraduate OHP clinical programmes (Dentistry and Dental Hygiene and Therapy) and academic staff were invited to participate in the study by email. All potential participants were given information regarding the study, including proposed focus group dates and times and the participant information sheet. Participants were asked to reply to the email outlining their interest, understanding of the project, and availability for the proposed dates.

Structure of the Intervention

In-person, semi-structured focus groups were planned across numerous days in December 2023 and January 2024. Each focus group was 45 minutes. To avoid bias and the potential for influencing discussion, separate focus groups were arranged for staff and students. Based on previous research, the focus groups were limited to four to five participants [329]. The focus groups were facilitated by a trained researcher (PhD candidate), and a script was developed to guide the facilitator and ensure standardisation across different sessions. The script was developed from previous research and discussions were centred around three learning outcomes from the recent ADEE ES consensus-based learning outcomes publication [326]. The script is provided in Appendix A.

Data Collection

The focus groups were audio-recorded and transcribed live by a trained researcher (co-author EG). In order to collect individual responses before the focus group discussion, WooClap (www.wooclap.com) was used, and participants were asked to respond to the questions asked by the facilitator. The individual responses were visible to all focus group participants, stimulating further discussion between the group. Each participant was given a code, which ensured anonymity but also allowed researchers to link earlier comments to the same participant.

Data Analysis

The audio recordings were transcribed and combined with the written notes from the session to produce the final transcripts. The transcripts and the data from the Wooclap individual responses were analysed by two separate researchers (PhD candidate and co-author EG). Descriptive statistics were used for the polls and demographic data, whilst all other data collected was analysed through thematic analysis. The two researchers independently completed the six-step process described by Braun and Clarke before meeting to gain consensus on the themes [315]. In this analytical approach, themes are developed due to perceived importance and relevance to the topic. Data saturation was established when no new themes were identified in the transcripts, and response repetition occurred. After data saturation was achieved, no further recruitment took place. However, all planned focus groups were completed.

Results

The total number of participants for the focus groups was 40, with 22 academic staff and 18 student attendees. Students enrolled in both clinical programmes participated in the study, and the year groups ranged from first to final year. Staff from nine different curriculum subjects attended the focus groups. The transcripts are available in the University of Sheffield open-access data repository: https://doi.org/10.15131/shef.data.25342006.v1. Data saturation was established after the

sixth focus group and 28 participants. Two-thirds (66%) of participants reported that all three learning outcomes were clearly written, and all participants felt the learning outcomes were relevant to the dental curriculum. All but two responses stated the learning outcomes were ‘essential’ or ‘important’. Thematic analysis generated five themes:

- Normalising the topic of Environmental Sustainability to support attitude and behaviour change
- Baseline knowledge transmission with relevant practical application
- Viewing and modifying existing teaching and assessment events through a different lens
- Environmental Sustainability transcends all disciplines of dentistry and oral healthcare
- Safeguarding against misinformation and disinformation

Relevance

This study provides important strategies to embed ES within an existing curriculum. Participants demonstrated significant support for the topic and identified many existing teaching and assessment methods that could be ‘augmented’ with ES content. Participants felt it is essential that ES is not considered a separate entity. It should be taught alongside and as part of existing dentistry and oral healthcare content. It was also noted that ES must be incorporated into all curriculum subjects; it is not a discipline-specific construct. The data collected in this study provides some core values that will inform the overall curriculum development project. Additionally, the concept of embedding ES within existing teaching and assessment methods, with minimal disruption, provides an interesting opportunity to explore through further research.

Environmental Sustainability: The Attitudes and Experiences of UK Students in the Oral Health Profession.

Introduction

Student support and input are critical for any curriculum development project to be successful. Previous surveys demonstrated significant support for embedding ES in the undergraduate OHP curriculum from a limited sample size [251,270,274]. Additionally, key strategies to engage students have not been explored.

Aim

This study aims to understand students' attitudes to ESD, explore the extent to which ESD is included in the curriculum, and identify ways to increase awareness of ESD within the curriculum.

Methodology

Ethical approval was obtained for this study from the Dentistry Ethics Committee at the School of Clinical Dentistry, University of Sheffield (application number 044529). An online questionnaire was used to fulfil the aims of this study. After piloting with local students, the survey was disseminated via the Dental Schools Council to all UK-based students enrolled on either Dentistry or Dental Hygiene and Therapy programmes. The survey included 13 questions, with a variety of closed and open questions used. Descriptive statistics were used to analyse the closed-ended questions, and thematic analysis was used to analyse the free-text responses.

Results

A response rate of 68.4% was achieved for this study after 263 students from 13 different schools completed the survey. 95.4% of students were either 'concerned' or 'very concerned' about ES daily. Most students (85.6%) believe that providing oral healthcare in an environmentally sustainable manner is their responsibility, and 97.3% of students feel

the profession should be more actively engaged in ES. Students reported professional talks (74.9%), social media (66.4%) and clinical tutor-led discussions (58.9%) as the optimum strategies to raise awareness regarding ESD. Free-text responses suggest that students would prefer ESD content to be evidence-based and not be an addition to other curriculum elements. Almost all respondents (97.7%) reported that being taught ESD in their undergraduate programme would positively impact the environmental impact of future oral healthcare they provide.

Relevance

This study demonstrates significant support for ESD from OHP students in the UK. The vast majority of students feel that delivering environmentally sustainable dentistry is their responsibility and report that embedding ES in the curriculum is critical. Students proposed evidence-based talks and tutor-led discussions as key strategies to teach ESD but were concerned about additional content in an already overloaded curriculum. Embedding cross-discipline topics such as ES in the curriculum requires careful consideration to ensure the subject is taught effectively and still fits within the constraints of the existing curriculum.

Environmental sustainability: the attitudes and experiences of UK students in the oral health care profession

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Key points

- A comprehensive multi-centre survey of students in UK oral health professions, including Bachelor of Dental Surgery and dental hygiene and therapy students, was undertaken to provide insight into the current level of environmental sustainability in dentistry education provided to undergraduate students in the UK.
- Barriers and drivers are identified by students for their engagement with environmental sustainability in dentistry.
- There is a need for further discussions regarding the impact that oral health care provision has on the environment and provides suggestions on how further information about environmental sustainability in dentistry could be shared with students/professionals alike.

Abstract

Objective This study aims to provide insight into the attitudes and perspectives of undergraduate dental students from UK dental schools regarding environmental sustainability in dentistry (ESD) and the manner and extent in which ESD is included in the current undergraduate oral health care curricula.

Methods This study is a multi-centre, nationally representive study involving a cross-sectional online survey of undergraduate Bachelor of Dental Surgery and dental hygiene and therapy students in UK-based dental schools. Data analysis was conducted through descriptive statistics and thematic analysis.

Results In total, 263 students from 13 UK schools completed the survey, resulting in a national school response rate of 68.4%. Key findings are: 97.3% of students believe that the dental profession should be more actively engaged in environmental sustainability but students currently have very little exposure to ESD at an undergraduate level; and 76.8% of students expressed that they are concerned about the impact that oral health care provision has on the environment, but only 23% of students have independently researched ESD.

Conclusions Students identify that oral health care professionals should become more engaged in efforts to mitigate the negative impacts from our activities on the environment, principally via education at all levels. The data from this study provide insight into the current level of awareness and concerns for the environmental impacts of oral health care provision, and are a powerful driver for the inclusion of ESD into the undergraduate curriculum in UK based dental schools.

Introduction

Sustainability in oral health care

The recently published COP26 special report on climate change and health, highlights the impact of health care on the environment,[1] with evidence of how 'health professionals worldwide are already responding to the health harms caused by this unfolding crisis'.[2] Health care systems are responsible for around 5% of global greenhouse gas emissions, of which oral health is an important contributor.[3,4] The delivery of general health care is currently not environmentally, socially or financially sustainable due to high amounts of CO_2e (carbon dioxide equivalent) and waste generated.[3,4,5,6]

To date, advancements made by the oral health care community have been largely focused on the end goal of preventing and managing oral diseases. We now have an appreciation that these laudable intentions and efforts are having the unintentional consequence of contributing to the global net rise in CO_2e emissions and pollution.[7]

The oral health care profession has a responsibility and vital role in climate change mitigation efforts through comprehensive engagement in sustainable practices. Sustainable oral health care could result in substantial CO_2e reductions, reduced plastic usage and waste generation, leading to enhanced patient care, staff satisfaction, cost savings and improved quality of life.[8,9,10]

Sustainability awareness through education

Education is considered as the fundamental component of any remediation strategy, with a focus on increasing awareness and identifying remediation solutions for each sector and for the supply chain as a whole.[11,12] Effective education programmes should include communication, dissemination and participation at all levels.[13,14]

There is an increasing understanding of the structure and content of 'sustainability' knowledge required at an undergraduate level.[5,7,11,12,15,16,17] Essentially, the focus of

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Refereed Paper.
Submitted 25 August 2023
Accepted 3 October 2023
https://doi.org/10.1038/s41415-024-7135-z

environmental sustainability in oral health care is on the delivery of a good oral health care strategy that considers the four domains: effective preventive care regimes; good operative care; integrated patient care; and professional ownership of care. These domains apply to all aspects of the management of systemic diseases and by targeting them jointly it benefits the patient and society with low environmental impacts.[18,19] Educational messages should focus on disease-prevention regimes with sustainable oral hygiene practices at home. The Association for Dental Education in Europe (ADEE) has been a key driver to embed environmental sustainability in oral health professional (OHP) curricula at a European level. Two consensus documents have been published from special-interest group meetings at the annual ADEE conference. The first was an initial scoping document to identify a need to embed environmental sustainability and consider key messages to begin teaching this concept.[15] The second is a publication of consensus-agreed specific learning outcomes and recommendations for teaching, learning and assessment for environmental sustainability.[20] In addition, the O-Health-Edu vision for OHP education in Europe, published after sector-wide consultation, incorporates environmental sustainability as a key element.[20] With educational bodies such as ADEE increasingly publicising its positive views towards the inclusion of environmental sustainability in dentistry (ESD) into the curriculum, there is hope that universities and other governing bodies will follow suit in recognising the impact that dentistry has on the environment and how education is a key strategy to a more sustainable future.[21] In the formative years of the oral health care undergraduate curriculum, there is an invaluable opportunity to increase awareness and remediation actions through carefully channelled educational programmes.[7]

For any educational approach to be successful, it is essential to obtain and consider the attitudes of students as the recipients and co-managers of their education. Two recently published studies consider this in a UK and USA setting.[22,23] Both studies had similar aims with regards to assessing the current level of ESD being taught to pre-doctorate/undergraduate students and assessing the students' level of interest and desire for a change in their curriculum.

Joury *et al.* (2021) gathered opinions from both students and educators across two dental schools in the UK and in the USA.[22] The study demonstrated a positive attitude towards the inclusion of ESD into the curriculum, more specifically from students rather than educators. It highlighted the importance of having a 'bottom-up' approach, where end-users help guide policy that is complemented by a 'top-down' approach (paternalistic guidance from key governing organisations), from either the General Dental Council (GDC) or US equivalent, to create a legitimacy to the cause. The study by Gershberg *et al.* (2021) focused on dental students in US-based dental schools only.[23] They found that despite other health professional courses already embedding environmental sustainability in their respective curricula, dental schools have not yet followed suit. Gershberg *et al.* found that students have expressed their concern about the impact that the provision of oral health care has on the environment and found a baseline eagerness for ESD to be included in the curriculum.

Both these studies have provided the foundation to push the ESD agenda into the curriculum in US-based dental schools, by showing that there is a drive from students to have more ESD-based content throughout the course. Nevertheless, further research into the levels of ESD within the dental curriculum is needed to better understand the particular requirements of the students. Students are a key stakeholder of OHP education and as such, the student voice is essential in any intervention to improve education or to integrate new concepts.

This study aims to provide further clarity and focused detail into the students' attitudes and behaviours towards ESD in the provision of oral health care. Also, the manner and extent to which ESD is included (currently and in the future) into the undergraduate oral health care professional curricula. This study focuses on the perspective of undergraduate dental students (Bachelor of Dental Surgery [BDS]) and dental hygiene and therapy students (DH&DT) from UK dental schools, as a national representative case study.

Materials and methods

A multi-centre, cross-sectional online survey of undergraduate BDS and DH&DT students was carried out using an online questionnaire that was distributed to all UK-based dental schools. Ethical approval was obtained from the University of Sheffield's Research Ethics Committee (Application 044529). Consent was gained through a 'participation statement' that prospective participants had to read and approve before continuing onto the survey questions. Support for this study was obtained from the UK Dental Schools Council.[24] Participation requests were sent to the Heads of School of 19 UK dental schools for onward internal distribution among all the undergraduate BDS and DH&DT student cohorts of each respective school. The validity of the questionnaire was tested through two focus groups of students at the authors' institution. The survey consisted of 13 questions that included closed and open questions – Likert scale as well as multiple-choice questions. Likert scales allowed for a wider range of answers to be collected to improve the clarity of the questions and allow for quantification of the data. Multiple-choice questions were used to focus responses into key categories and a free-text section was included to identify barriers that they personally face that hinder them from increasing their understanding of ESD and their ability to apply this knowledge in a clinical environment.

All close-ended questions were analysed through descriptive statistics and the data were presented as graphs or charts using Google Forms auto-generated software. Thematic analysis was used for the single open-ended question as per Braun and Clarke's (2006) six-phase approach and resulted in the development and refinement of themes.[25]

Results

Students from 13 schools completed the survey, resulting in a school response rate of 68.4%, showing a strong representation of this student population across the UK. Six schools did not respond or wish to participate, identifying student survey fatigue and academic burden as a concern.

The student response rate (as a function of the total number of registered undergraduate students) was 24.5%, with a total of 263 students taking part in the survey from across 13 UK-based dental schools.

From the written responses, it is clear that the students had varying degrees of clinical experience dependent on individual levels of progression in their respective courses, with the following key findings as depicted in Figure 1 and Table 1:

- There was no difference in opinions of students at different stages of progression within their own dental school curriculum, all showing equal interest in their profession's environmental impact

Fig. 1 Responses demonstrate the level of concern students express towards environmental sustainability in everyday life

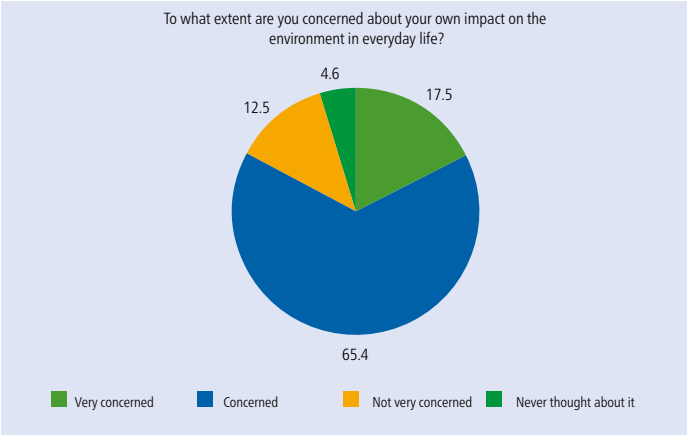


Table 1 Understand students' level of concern about the environment

To what extent are you concerned about your own impact on the environment in everyday life?	
Very concerned	46 (17.5%)
Concerned	172 (65.4%)
Not very concerned	33 (12.5%)
Never thought about it	12 (4.6%)
To what extent do you try to reduce the environmental impact of your daily activities?	
I always try	71 (27%)
I sometimes try	142 (54%)
I would like to do more but don't know how	42 (16%)
I don't really try	7 (2.7%)
Not my problem, it is the responsibility of the authorities and government	1 (0.4%)
Have you considered if the provision of oral health care has an impact on the environment?	
Yes	237 (90.1%)
No	26 (9.9%)
With regards to the last question, please read the following carefully and tick all that apply:	
The environmental impact is negligible and can be ignored	3 (1.1%)
Society has bigger environmental problems to worry about that should focus or attention	38 (14.4%)
The provision of oral health care is my priority as a clinician and this has unavoidable environmental consequences that we need accept	122 (46.4%)
As clinical oral health care workers we have enough to worry about; our job is hard enough and sustainability concerns are not part of our job	16 (6.1%)
It is our responsibility, as oral health care workers, to provide care in an environmentally sustainable manner	225 (85.6%)
How concerned are you about the effect of oral health care on the environment?	
Unconcerned	4 (1.5%)
Neither	57 (21.7%)
Concerned	202 (76.8%)

- The level of concern for their own personal environmental impact identified that 77.9% of respondents were concerned, of which 17.5% were very concerned (Fig. 1)
- Despite this apparent level of baseline concern, only 27% of respondents 'always try' to reduce their personal impact on a day-to-day basis, compared to 54% sometimes trying
- A total of 16% of respondents stated that 'I would like to do more but don't know how' (Fig. 2)
- In total, 90% of students have considered the impact that the provision of oral health care has on the environment, with 85.6% believing that it is our responsibility as oral health care workers to provide care in an environmentally sustainable manner
- And 46.4% believe that 'the provision of oral health care is my priority as a clinician and this has unavoidable environmental consequences that we need accept' (Table 2). One student responded that 'environmentally friendly solutions always seem to contradict infection control and therefore cannot be done for patient safety'. Cross-infection control and being in a hospital setting were identified by students as barriers to them engaging with impactful solutions at an undergraduate level.

Regarding students' own level of concern for the effect that the provision of oral health care has on the environment, 76.8% expressed that they are concerned. This was conveyed in the free-answer question, with many students identifying cross-infection control policies and procedures, specifically the use of single-use plastics and personal protective equipment (PPE), as a barrier to them engaging with impactful solutions to make the provision of oral health care more sustainable. A common view among many dental students on this topic was clearly expressed by one particular statement: 'as dental professionals we use a lot of plastic single-use items due to cross infection, but this is very concerning to me and wish there was another way to be more sustainable'.

A further common finding was their perceived lack of power within the hierarchy of a hospital setting and that their 'student voice' lacked any form of influence. This sentiment is captured by the comment 'as a student we just follow the protocols and guidelines set out by staff or the hospital or the trust the hospital is a

part of. It doesn't feel like we can do anything to change any of it'. A suggestion captured in the responses is to create a mechanism that allows students to have a greater voice with regards to ESD within dental schools. For example, the introduction of sustainability action groups that allows like-minded students and staff to convene and discuss local strategies and action plans to that will make a difference. Sheffield Dental School introduced the Sheffield Oral Sustainability group in 2022; this group has allowed students to partake in local campaigns to promote ESD. Students have expressed that after 'joining a sustainability group, I feel more positive about this and feel like my voice is more heard'.

In total, 23.2% of undergraduate students were neither concerned or unconcerned about the effect of oral health care on the environment. Another barrier identified by students was a lack of care and/or a lack of time. Many students have the view that 'it's hard enough to do the whole course without having the extra worries, I think it should become more of a concern once you are a practising clinician rather than as a student'.

Currently, there is very limited exposure to undergraduate students about the effect that oral health care provision has on the environment, with 51% saying it's only been mentioned briefly through staff members or informal conversations with peers (53.2%) (Table 3). Only 9% of students believe that they have been taught ESD through more formal means such as lectures. However, despite this lack of current emphasis in the curriculum, 97.3% of students believe that the dental profession should be more actively engaged in ESD (Fig. 3).

Current level of student engagement in ESD

Despite a desire for greater education in ESD, students are unlikely to proactively seek information about it, as only 23% of respondents independently researched ESD outside of the undergraduate curriculum, either part of a group or independently (Table 3), with 76.4% admitting to not doing any additional research on the topic. This implies students will only engage with ESD if it is part of the curriculum and not optional or extra-curricular, as students feel they lack the time to research ESD independently, typified by the comment 'the effect we have on the environment is not taught to us and not much time is available to research this'.

Fig. 2 Results identify students' current level of proactivity regarding reducing their personal impact on the environment

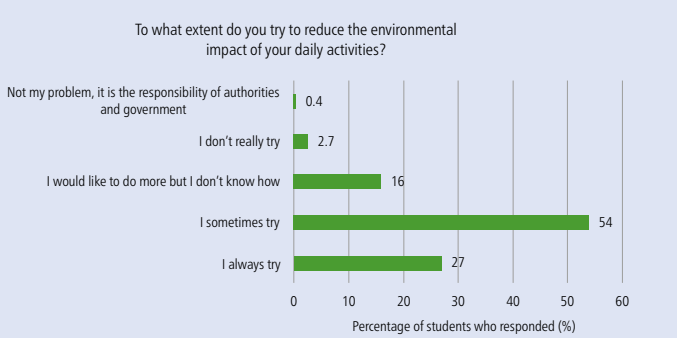


Table 2 Understand students' level of awareness of the impact that oral health care provision has on the environment

Have you considered if the provision of oral health care has an impact on the environment?	
Yes	237 (90.1%)
No	26 (9.9%)
With regards to the last question, please read the following carefully and tick all that apply:	
The environmental impact is negligible and can be ignored	3 (1.1%)
Society has bigger environmental problems to worry about that should focus or attention	38 (14.4%)
The provision of oral health care is my priority as a clinician and this has unavoidable environmental consequences that we need accept	122 (46.4%)
As clinical oral health care workers we have enough to worry about; our job is hard enough and sustainability concerns are not part of our job	16 (6.1%)
It is our responsibility, as oral health care workers, to provide care in an environmentally sustainable manner	225 (85.6%)
How concerned are you about the effect of oral health care on the environment?	
Unconcerned	4 (1.5%)
Neither	57 (21.7%)
Concerned	202 (76.8%)

It is important for us to acknowledge that eco-anxiety is recognised as a true emotional response to the predicted impact of climate change and is defined as 'a chronic fear of environmental doom'.[26,27,28] One student authenticated this fear leading to an avoidance of the topic by saying 'the environmental impacts of dentistry etc can feel very overwhelming. This is not a feeling which results in productive action'.

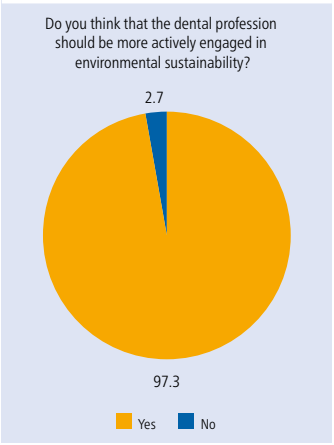
Methods for improving engagement with students

Students identified social media (66.4%), professional talks (74.9%) and tutor-led discussions (58.9%) as the best way to increase awareness of the impact that oral health provision has on the environment (Fig. 4). This, combined with opinions such as 'I think a compulsory attendance tutorial with no extra work could be a good way of delivery the teaching', suggest that students have a preference for information on ESD to be delivered from credible sources, in a manner that does not significantly increase their workload. However, despite expressing interest in attending professional seminars relating to ESD, students face a significant barrier in that the majority of these events are aimed at qualified clinicians and therefore require a UK GDC number to register, something students do not possess.

In total, 97.7% of respondents have said that being taught ESD at an undergraduate

Table 3 Identify if student environmental concern are a driver for inclusion of environmental sustainability in the undergraduate curriculum	
Do you think that the dental profession should be more actively engaged in environmental sustainability?	
Yes	256 (97.3%)
No	7 (2.7%)
During your undergraduate degree, have you been exposed to the concept of environmental sustainability? Please tick all that apply:	
Never exposed	62 (23.6%)
Formal lectures	24 (9.1%)
Briefly mentioned by staff members	134 (51%)
Students society talks/activities	46 (17.5%)
Informal conversations between peers/friends	140 (53.2%)
Would you like your undergraduate dental course to include a greater emphasis on environmental sustainability?	
Yes	223 (84.8%)
No	40 (15.2%)
Have you personally or as part of a group, ever taken a pro-active approach to learning about oral health care and its environmental impact?	
Yes	62 (23.6%)
No	201 (76.4%)
How do you think that we can increase awareness of the impact that oral health care provision on the environment within the undergraduate curriculum?	
Through social media	174 (66.2%)
Professional talks	197 (74.9%)
Student led societies	121 (46%)
British Dental Students Association	139 (52.9%)
Tutor facilitated group tutorials	155 (58.9%)
Do you think that increasing our knowledge of environmental sustainability in oral health care will have an impact on our future profession and the environment?	
Huge positive impact	84 (31.9%)
Some positive impact	173 (65.8%)
No impact	6 (2.3%)
Negative impact	0 (0%)

Fig. 3 Shows that 97.3% of students believe that the dental profession should be more actively engaged with environmental sustainability



Barriers to engagement – identified by the student community

Seven key themes were identified by students as barriers to engagement in solutions for managing the effects of oral health care on the environment. These are (listed in the order of incidence of responses):

- Hierarchy of a hospital setting (27% of responses)
- Lack of knowledge (23.2%)
- Cross-infection control policy, especially with regard to COVID-19 pandemic (16.4%)
- Lack of time (8.2%)
- Eco-anxiety (6.1%)
- Lack of care (3.7%)
- Limited knowledge base within academic tutors (3.7%).

level would have a positive effect on the future impact that dentistry as a profession has on the environment. No participants said that it would have a negative impact and only 2.3% believe that there will be no impact by as a result of the change (Table 3). These results show an overwhelming support for increasing awareness and education surrounding the environmental impact of dentistry, suggesting a very positive student response to the inclusion of ESD into the curriculum.

The GDC recently distributed their Safe Practitioners domains for consideration and commentary, which included two learning outcomes relating to environmental sustainability, inspired by the ADEE's 2022 conference that specifically discussed sustainability in dental education.[21] The learning outcomes include: describing the main principles of sustainable oral health care; any challenges or barriers to implementing ESD; and understanding the environmental impact of common treatments. If agreed upon and included, this is a positive first step into the implementation of ESD learning objectives into the UK undergraduate dental curriculum. This also highlights that sustainability is a topic that is going to be a common theme in the provision of oral health care in coming years and something that will impact all practitioners.

It should be noted that 2% of respondents did not believe there were any barriers in place and 9.2% did not respond to the question.

The barriers identified confirmed the findings raised throughout the survey. Students identified that their main barrier to becoming more sustainable while at dental school was the hierarchy present within hospital settings and the standard operating procedures and policies put in place by management. This was summarised by one student: 'as students, we do not have as much impact/authority to help create a change...following correct procedure for PPE is a main thing that prevents us from reducing waste'.

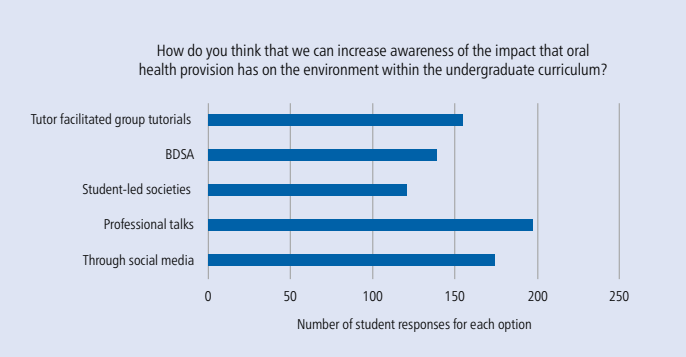
Discussion

This study sought to determine the attitudes and opinions from undergraduate BDS and DH&DT students for the inclusion of ESD into their curricula. The strong student response rate, with a 68% representation from a total of 13 UK dental schools, indicates that this topic is of significant interest and concern to the undergraduate population. As a cohort, current undergraduates have a strong baseline level of concern (65%) with regards to the environment. The 90% of students who considered the impact on the environment that arises from the provision of oral health care is reassuring and shows a wide level of awareness across the cohort, as identified in other sectors[29],[30]. However, this finding is worryingly diluted by the fact that nearly half of the respondents (46.4%) identify that the environmental impact from oral health care provision 'is an unavoidable consequence that we need to accept'.

There is no doubt that students are concerned (77.9% concerned and 17.5% very concerned) about the manner in which their personal activities impact on the environment but this is worryingly dampened by a lack of translation of environmental attitudes to actual behaviour change, identified by a 54% of respondents that identify as 'sometimes try to reduce their personal impact on the environment on a daily basis'. The majority of students appear to have an understanding of how to be more environmentally friendly but do not always see this as significant when it comes to their everyday life. It is therefore important when introducing ESD into the curriculum to impress on students the importance of being environmentally sustainable as often as possible, both personally and professionally. It has been identified that clinicians often find it difficult to transfer their home-based behaviours into a clinical setting due to a shift in mindset from environmental citizenship to professional clinical duties. In order to overcome this issue, it is important for members of the dental team to be open to conversations and education on the topic. Once ESD has become a common topic, steps can be taken to implement real actions into the workplace.[18]

Nearly one-quarter of the cohort (23.2%) showed ambivalence towards the effect of oral health care on the environment, identifying that this was a distraction from their studies, creating an additional time and content burden. The majority of students (76.4%) did not engage in any further formative, self-directed learning in ESD outside their curriculum. Students identified a number of reasons for this, highlighting a lack of time, lack of resources, not knowing where to find the correct resources and eco-anxiety. Providing students with the guidance and baseline knowledge of environmental sustainability, with an emphasis on oral health care provision, would empower students to do further research on the topic without feeling lost or overwhelmed. Interestingly and despite their reticence or difficulties to engage as undergraduate students, there was overwhelming support (97.3%) for greater engagement of the (qualified/practising) dental profession in ESD. Despite the overall guarded responses to the inclusion of sustainability in the curricula, students overwhelmingly (97.7%) accepted that such a move would have a positive effect on the future impact that dentistry as a profession has on the environment.

Fig. 4 Students identified social media, professional talks and tutor-led discussions as the best way to increase awareness of the impact that oral health provision has on the environment



These results highlight the importance of creating clinical guidelines and protocols in dental hospitals with environmental sustainability in mind, as this would provide students with first-hand experience in providing more sustainable oral health care while in education and as a practising professional.

In terms of delivery modalities, a blend of different formats was considered and advocated, with representation from social media, tutor-led discussions and professional guest presentations/webinars. Social media is a powerful tool that can be utilised to disseminate awareness and information relating to ESD in a manageable and effective manner. It has the potential to make sustainability a more achievable and understandable goal for dental professionals. The FDI World Dental Federation does this through the use of social media (#SustainabilityinDentistry), alongside promoting engagement in their sustainability challenges, which helps to promote more sustainable practice within dental practices.[31]

Overall, the results from this study provide a useful insight into current perspectives from undergraduate BDS and DH&DT students with regards to the topic of ESD in their curricula. Students are concerned about the impact of their (current and future) professional activities on the environment. It is very clear that in order to gain maximum engagement from students, ESD should be integrated into the curriculum. This would increase enthusiasm and engagement, as the inclusion of ESD within the undergraduate curriculum is viewed in a positive light by all students surveyed.

Conclusions

There is a clear recognition that ESD is not consistently taught in the undergraduate curriculum in dental schools across the UK. All respondent students identified the inclusion of ESD within the undergraduate curriculum as a positive development. They also identified that ESD should be included in the student curricula in a seamless and fully integrated manner and in a manner that it does not create a further burden to learning and teaching. Through education on the environmental impact of dentistry, students, as emerging oral health care professionals, will be better informed to practise dentistry in

a more environmentally sustainable manner, for the benefit of their patients and the planet.

Ethics declaration

The authors declare that they have no conflict of interest.

Ethical approval was obtained from the University of Sheffield's Research Ethics Committee (Application 044529). Consent was gained through a 'participation statement' that prospective participants had to read and approve before continuing onto the survey questions.

Data availability

Data supporting this publication can be freely downloaded from the University of Sheffield Research Data Repository at https://doi.org/10.15131/shef.data.24657627, under the terms of the Creative Commons Attribution (CC BY) licence.

Author contributions

Conceptualisation: Steven Mulligan and Nicolas Martin. Project design: Steven Mulligan, Nicolas Martin, Olivia Durnall and Jonathan Dixon. Project execution: Olivia Durnall, Steven Mulligan, Jonathan Dixon and Nicolas Martin. Initial writing: Olivia Durnall and Steven Mulligan. Results and interpretation of data: Steven Mulligan, Nicolas Martin, Olivia Durnall and Jonathan Dixon. Final writing and editing: Nicolas Martin, Olivia Durnall and Jonathan Dixon.

Acknowledgements

The authors thank the UK Dental Schools Council for supporting this study with proactive dissemination of the survey among its member institutions. We thank the individual deans and heads of departments for further promoting this study within their own institutions and we express our sincere gratitude to the actual student respondents for their active and willing participation.

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Chapter VII – Developing Subject-Specific Educational Content for Environmental Sustainability in Dental Education

Previous research has demonstrated that embedding environmental sustainability (ES) in the undergraduate dental curriculum requires careful and strategic integration and interweaving of the topic throughout the curriculum [13,326,327]. The realisation that ES is relevant to all disciplines of dentistry means that all academic staff need to consider ES and its relevance to their teaching. However, it is clear that the overloaded curriculum, a lack of educator expertise and practical guidance are significant barriers that complicate this process [327].

The included peer-reviewed manuscript [327]:

> ***Dixon J**, Field J, Gibson E, Martin N. Curriculum Content for Environmental Sustainability in Dentistry. Journal of Dentistry. 2024 Apr 26;105021.*

provides evidence-based and subject-specific content statements for oral health professional (OHP) educators. The content statements have been mapped to all dental curriculum subjects and allow educators of all disciplines to integrate evidence-based content on ES in their teaching. The statements are concise and can be considered 'key messages' for environmental sustainability in dentistry (ESD) and oral healthcare. Supporting content is included to provide additional context and evidence-based information for educators.

Candidate Contribution

The PhD candidate was the principal investigator for this research project and conceptualised the design of the study, developed the research protocol, and provided the most significant contributions to project implementation, data curation, analysis and write up. The PhD candidate also led the extensive consultation process, which included

leadership and communication with multiple stakeholders, including European educational bodies, discipline experts and students. The PhD candidate also led the peer-review process and manuscript proofing.

Curriculum Content for Environmental Sustainability in Dentistry

Introduction

Previous research within this project has demonstrated that dental schools and educators still face numerous practical barriers to embedding ES within the curriculum including:

i. A lack of space in the existing curriculum to add new topics
ii. Limitations in knowledge to teach and assess ES
iii. No published guidance on how to embed ES in a practical sense

To overcome these, a pragmatic and evidence-based approach is needed. As ES should be taught across all disciplines, developing content for educators that can be incorporated into existing teaching and assessment events is potentially a viable strategy to overcome these challenges.

Aims and Objectives

The aim of this study is to create high-level evidence-based and subject-specific ES content through an approach grounded in collaboration with key stakeholders in dental education.

The objectives are:

- To create, categorise and map evidence-based and subject-specific content statements for ESD.
- To undertake a stakeholder consultation to ensure that the content statements are fit for purpose.

Methodology

The research evolved over five steps:

1. *Identification of core sources:* an extensive literature search was completed to ensure all relevant and recent literature was included. The search ran from August 2021 to January 2024 using the MEDLINE database, and 16 different search terms were used.
2. *Theme generation and organisation:* themes were identified from the literature search, which allowed for the appropriate organisation of mass amounts of content before content statement development.
3. *Content statement development:* three researchers (PhD candidate, co-authors NM, JF) wrote the content statements through an iterative process. The researchers used their experiences in the field of ES and OHP education to create statements with sound pedagogic principles.
4. *Identification of curriculum subjects/disciplines and mapping the content statements:* an extensive list of curriculum subjects (19 in total) was created after reviewing the European professional qualifications directive and the webpages of national associations [36]. Two researchers (PhD candidate and co-author NM) subsequently mapped the content statements to the relevant subject(s). Disagreements were resolved through discussion with a third researcher (co-author JF).
5. *Consultation process:* Three separate consultation processes were completed to ensure the content statements, and the mapping process were valid. Students were approached to ensure the content statements were clear and easy to understand. Discipline experts were asked to validate the mapping process for their area of expertise, and European educational experts were asked to comment on the educational rationale of the overall methodology and the individual statements.

Results

The consultation processes received responses from nine students, 17 educators from 16 different curriculum subjects, and three European education experts. Forty-four content statements were finalised after the consultation processes. The content statements were

organised into 11 themes, ranging from raising awareness and behaviour change to specific strategies that counteract individual environmental contributors, such as travel or waste management. The mapping process demonstrated that numerous content statements were relevant for *all* clinical disciplines and could potentially be taught similarly, while some statements are more disparate and relate to individual curriculum subjects.

Relevance

The evidence-based and subject-specific content statements presented in this study should allow educators to embed ES within their teaching events. The content statements serve as 'key messages' for ES. These may be included as additional slide(s) in existing lectures and seminars, thus avoiding the need to add more teaching events for ES in an already overloaded curriculum. The extensive search strategy and consultation processes should give educators confidence that they are delivering evidence-based information to their students.

Journal of Dentistry 147 (2024) 105021

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Curriculum content for Environmental Sustainability in Dentistry

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ARTICLE INFO

Keywords:
Environmental Sustainability
Dental education
Curriculum content
Oral Health Professionals
Dental Hygienists

ABSTRACT

Objectives: (i) To identify suitable strategies and opportunities to embed Environmental Sustainability (ES) within an existing Oral Health Professional (OHP) curriculum through a series of focus groups with students and academic staff and (ii) To create high-level evidence-based and subject-specific ES content through an approach grounded in evidence and collaboration with key stakeholders in OHP education.
Methods: Focus groups were used to explore academic staff and student views on appropriate teaching and assessment methods for ES. Content statements were developed from an extensive literature search, mapped to curriculum subjects, and validated through consultation with students, discipline-experts and education-experts.
Results: Five themes were identified from the focus groups: ES transcends all disciplines of dentistry and oral healthcare; baseline knowledge transmission with relevant practical application; viewing and modifying existing teaching and assessment events through a different lens; normalising the topic of ES to support attitude and behaviour change and safeguarding against misinformation and disinformation. Forty-four content statements were developed and mapped to nineteen curriculum subjects.
Conclusions: This study identifies for the first time a comprehensive strategy for the inclusion and delivery of ES (method and content) in the curriculum. A novel method to define and map curriculum content has been explored and validated using a range of complementary methodologies. A comprehensive and robust list of evidence-based and subject-specific educational content statements have been defined in the field of Environmental Sustainability in dentistry and oral healthcare.
Clinical Significance: Oral healthcare has a significant environmental impact, the key to all mitigation strategies is educating the profession at all levels.

Introduction

Oral health professional (OHP) curricula must be responsive to the changing societal and educational landscape to ensure graduates can meet the demands of the profession for the present and the future. As a regular quality assurance measure, a curriculum should have in-built sustainability achieved through a development process to allow appropriate periodic review of material content and delivery [1,2]. Curricula typically develop over time in response to three principal drivers: new developments in the discipline (dentistry and oral healthcare), changing educational rationales and innovations and pressures from wider stakeholders [3–8].

Environmental Sustainability (ES) and climate change are challenges that transcend all sectors. The United Nations Brundtland Commission defined Sustainability as: "*Meeting the needs of the present without compromising the ability of future generations to meet their own needs*" [9].

The significant environmental impact of oral healthcare, particularly in relation to carbon dioxide equivalent emissions, pollution and waste generation has been highlighted and quantified in the literature [10–12]. These impacts principally relate to staff commute, patient travel, procurement, energy and water consumption and waste generation.

Introducing Environmental Sustainability into Oral Health Professional education

The need to embed ES within OHP education at all levels (undergraduate, postgraduate, and continuing professional development) has been established [13–16]. The Association for Dental Education in Europe (ADEE) has been at the forefront of this drive with the 'Sustainability in Dentistry' Special Interest Group activities, that have been reported in two published consensus reports [13,14]. These reports (i)

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https://doi.org/10.1016/j.jdent.2024.105021
Received 7 March 2024; Received in revised form 20 April 2024; Accepted 23 April 2024
Available online 26 April 2024

identify the need to embed ES within the OHP curriculum and (ii) recommend learning outcomes and methods of learning, teaching, and assessment of ES. Similarly, the FDI World Dental Federation is actively promoting ES through education in all settings with a wide range of impactful resources and publications [16–19]. Staff and student support for introduction of the topic into undergraduate education has been demonstrated in multiple surveys [20–23].

An example of implementation at a national level is the General Dental Council in the United Kingdom (UK). The regulator has adopted some learning outcomes from the ADEE European consensus report in the recent Safe Practitioner Framework publication [24]. This mandates that ES is taught and assessed in UK dental schools from September 2025 and all graduates must demonstrate that they meet the learning outcomes from 2030.

The challenges associated with introducing Environmental Sustainability

Higher Education Institutions across the world are cognisant of the need to embed ES education across all their departments, including dental schools. This task presents a number of real challenges in OHP education, and it appears that many schools are not currently teaching or assessing ES, as identified in a recent pan-European survey [25]. The profession has sought to address this deficit with the publication of guidance and recommendations that address the conceptual implementation challenges [13,14]. The ADEE consensus statements remain the only guidance for educators who need support in embedding ES within their local curriculum. The documents promote ES and establish a need, as well as proposing learning outcomes to be taught and assessed. Notwithstanding, several practical barriers remain to embed and implement ES in the undergraduate dental curriculum [21,22,26], that include:

- A perceived lack of knowledge to teach ES.
- Time constraints due to the overloaded nature of existing curricula.
- A lack of practical guidance and resources for educators and students.

The aims of this research are two-fold:

- Identify suitable strategies and opportunities to embed ES within an existing curriculum through a series of focus groups with OHP students and academic staff.
- Create high-level evidence-based and subject-specific ES content through an approach grounded in collaboration with key stakeholders in OHP education.

The objectives to meet these aims are:

- To explore the opinions of academic staff and students on strategies to teach and assess selected ES learning outcomes within undergraduate OHP curricula.
- To create, categorise and map evidence-based and subject-specific content statements.
- To undertake a stakeholder consultation to ensure that the content statements are fit for purpose.

Materials and methods

The aims and objectives were achieved through two exploratory investigations:

- Workstream 1: Explore the views of academic staff and students to embedding Environmental Sustainability in the curriculum - A qualitative approach
- Workstream 2: Develop and map content statements for Environmental Sustainability to subjects within the dental curriculum - A multi-stakeholder consultation

Explore the views of academic staff and students to embedding Environmental Sustainability in the curriculum - A qualitative approach

This intervention received approval from the Dentistry Ethics Committee at the School of Clinical Dentistry, University of Sheffield (application number 056582). Focus groups were used to achieve the aims of this research.

Recruitment

Academic teaching staff (clinical and non-clinical) across all departments of the authors' academic institutions and students registered on undergraduate clinical programmes (Bachelor's Degree in Dentistry Surgery and Diploma in Dental Hygiene and Dental Therapy) were invited to participate in the study. The email invitation provided an overview of the project, proposed focus group dates and a more detailed participant information sheet. Interested participants were asked to respond by email to confirm their interest and availability. Additional recruitment measures were considered with provision to extend the focus group study if data saturation was not accomplished. All participants gave consent and clarity was provided regarding withdrawal of consent.

Structure of the intervention

Forty-five-minute focus group meetings were undertaken across multiple days between December 2023 and January 2024. Participants were grouped either as academic staff or students, no mixing amongst cohorts was permitted. Focus group sizes were limited to four and five participants. One experienced focus group facilitator (JD) chaired all the sessions having completed the required training. The focus groups were semi-structured, with a prepared script used to guide the facilitator to ensure reproducibility across all interventions. The script was developed from published research relating to curriculum development in OHP education [14,27,28]. The discussion centred around three learning outcomes taken from the ADEE learning outcomes publication, with participants asked to propose methods to teach and assess or observe each statement [14]. The three learning outcomes used were:

- Explain the importance of practising sustainable oral health care.
- Apply the scientific knowledge base in relation to the environmental impacts of common treatment methods, and common approaches to the delivery of care.
- Develop effective patient-specific strategies for preventive oral health, reducing the need for recall, operative intervention, and material use.

Data collection

The focus group discussion content was transcribed live by a trained researcher (EG) using Google Docs (https://www.google.co.uk/docs/about/#overview). Each focus group discussion was also audio-recorded and used to supplement the transcriptions where appropriate. The interactive presentation platform 'Woo Clap' (https://www.wooclap.com/) was used to gather independent thoughts that served as points of discussion for all attendees. During the discussions, participants were given codes that conferred anonymity and enabled effective matching and collation of statements.

Data analysis

Independent responses to the questions and the written transcriptions were analysed by two independent and trained assessors (JD, EG) using thematic analysis as described by Braun and Clarke [29]. The preliminary steps were completed independently and included data

familiarisation, coding, and theme development. The two assessors then met to reach consensus through discussion and if needed, re-evaluation of the transcripts. In this analytical approach, themes are created according to perceived relevance to the research question and not necessarily the prevalence of topics. Data saturation was determined when no new themes were identified in the transcripts.

Develop and map content statements for Environmental Sustainability to subjects within the dental curriculum - A multi-stakeholder consultation

Prior to development, the conceptual basis of this project was shared with academic staff and students to identify any early issues with feasibility and acceptability. The development and refinement of content statements followed five steps.

Identification of core sources

The evidence base for ES in oral healthcare was gathered through an extensive literature search that ran continuously from August 2021 to January 2024 to ensure all contemporaneous literature (English language) was included in the research. The search strategy was dynamic and evolved depending on the area of interest. The MEDLINE database was used to identify relevant sources and MeSH keywords were used. The core search terms used were:

- [Title]: sustain* AND dent*
- [Title]: sustain* AND oral
- [Title]: environ* AND dent*
- [Title]: environ* AND oral
- [Title]: eco* AND dent*
- [Title]: eco* AND oral
- [Title]: green AND dent*
- [Title]: green AND oral
- [Title/Abstract]: climate AND dent*
- [Title/Abstract]: climate AND oral
- [Title/Abstract]: life cycle AND dent*
- [Title/Abstract]: life cycle AND oral
- [Title/Abstract]: planet* AND dent*
- [Title/Abstract]: planet* AND oral
- [Title/Abstract]: waste AND environ* AND dent*
- [Title/Abstract]: waste AND environ* AND oral

There were no date limitations to the search strategy and all published articles that were relevant to the subject area were included.

Theme generation and organisation

Themes relevant to ES in oral healthcare were identified from the literature search. This process allowed the researchers to organise the subject area prior to writing the evidence-based statements.

Content statement development

The content statements were written and refined by three researchers (JD, NM, JF) who were led by the evidence base, and the themes generated from the previous steps. The researchers used their expert opinion in relation to ES and curriculum development to devise the statements with a pedagogic structure. This was an iterative process whereby researchers developed and refined multiple drafts through discussion until consensus was reached.

Identification of curriculum subjects/disciplines and mapping the content statements

A list of curriculum subjects was developed from the EU directive 2005/36/EC and national specialty bodies [30]; these were: Basic Sciences, Cariology, Periodontology, Endodontology, Paediatric Dentistry, Preventive Dentistry, Conservative Dentistry, Prosthetic Dentistry, Orthodontics, Oral and Maxillofacial Surgery, Oral Medicine and Pathology, Oral and Maxillofacial Radiology and Imaging, Oral Implantology, Special Care Dentistry, Dental Public Health and Community Dentistry, Dental Biomaterials, Dental Technology, Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management.

Each content statement was mapped to the relevant curriculum subjects by two independent researchers (JD, NM) through multiple rounds of discussion. Any disagreements were resolved through consultation with an additional researcher (JF).

Consultation process

To ensure the evidence-based and subject-specific statements were fit for purpose across relevant stakeholders in OHP education, three separate consultation processes were undertaken a with three different cohorts: students, discipline-experts, and education-experts.

The student consultation process was developed to review the clarity of language and ease-of understanding of the content statements. Clinical students from two dental schools in the UK were invited to comment. A Google Forms (https://docs.google.com/forms) survey link was created that included all content statements and a dichotomous answer of 'clear' and 'not clear' for each statement. All questions were mandatory with a further free-text option to comment on the 'not clear' responses.

The discipline-expert consultation process aimed to validate the mapping of content statements carried out by the researchers previously. Discipline experts from participating dental schools in the UK were invited to contribute to this process. Academics who teach these disciplines were invited to comment on the statements that were mapped to their area of expertise.

The final consultation process was disseminated through ADEE with the aim of acquiring the views of educationalists from across Europe. A consultation page was created on the ADEE website whereby the content statements and subject mapping were presented. Respondents were asked to provide their comments via a free-text box. The consultation process was shared in ADEE's monthly newsletter and via social media.

Comments from all three consultation processes were used to refine the content statements to ensure clarity of language and educational validity.

Results

Explore the views of academic staff and students to embedding Environmental Sustainability in the curriculum - A qualitative approach

A total of forty participants attended the focus groups, with a split of twenty-two academic staff and eighteen students from 8th December 2023 to 19th January 2024. Academic staff participants included academics from nine different curriculum subjects and ranged from clinical teachers (part-time clinicians) to professors. Students from both the undergraduate dental surgery and dental hygiene and dental therapy clinical programmes participated in the research, ranging from first year to final year students. Data saturation was reached in the sixth focus group and after twenty-eight participants, obviating the need to extend the study beyond the planned interventions. All planned and scheduled focus groups were conducted, even after data saturation had been achieved in order to ensure inclusivity of all views.

Thematic analysis of the transcriptions from the focus groups resulted in the generation of five themes. The themes and supporting quotes are presented in Table 1.

Develop and map content statements for Environmental Sustainability to subjects within the dental curriculum - A multi-stakeholder consultation

The literature search generated eleven themes which were principally derived from previous carbon modelling and scoping reviews on ES in oral healthcare [10,11,15,31]. These were: Raise Awareness, Behaviour Change, Reduce, Reuse, Recycle, Rethink, Good Quality Oral

Table 1
Themes identified through thematic analysis and supporting quote(s) from the focus group sessions.

Theme	Supporting Quote(s)
Normalising the topic of Environmental Sustainability to support attitude and behaviour change.	*"It should be mentioned in most lectures, so students automatically think about Environmental Sustainability."* *"It must be seen as a normal part of their practice on a daily basis and not a separate thing."*
Baseline knowledge transmission with relevant practical application.	*"It should be reinforced practically, and I think it should be embedded as you go through your course, not just a lecture on Environmental Sustainability and you are expected to know it."*
Viewing and modifying existing teaching and assessment events through a different lens.	*"It is a lens issue, we need to change our language."* *"It could be something as simple as modifying the patient management marking scheme to include Environmental Sustainability."*
Environmental Sustainability transcends all disciplines of dentistry and oral healthcare.	*"Students need to see the importance of Environmental Sustainability in every area of dentistry. Every educator needs to be thinking about Sustainability in their teaching."*
Safeguarding against misinformation and disinformation.	*"It is important that students know about life-cycle assessments (LCA's) to provide evidence-based facts and avoid disinformation."*

Healthcare, Knowledge Exchange and Research, Policy and Regulations, Environmental Impact – Travel, Environmental Impact – Procurement, Environmental Impact - Energy and Water Consumption, Environmental Impact - Waste Management, Dental Materials.

Fifty-one content statements were developed prior to the consultation processes. The student consultation process received nine responses. Thirty-nine statements were rated as 'clear' by all students, whilst twelve statements were rated as 'not clear' by at least one student. Seventeen educators across sixteen of the curriculum subjects responded to the ''discipline-expert' consultation process. Three educators responded to the ADEE consultation and provided some comments on language and mapping. Amendments were made considering all responses and forty-four content statements were finalised.

The content statements are presented in two tables. Table 2 presents the content statements with supporting content and the associated evidence base. Table 3 demonstrates the mapping process with the content statements linked to the applicable curriculum subjects. It was identified during the mapping exercise that some statements were applicable to *all* clinical subjects in the OHP curriculum, whilst others were linked to *fewer* subjects. To aid reading, all statements that have been mapped to clinical subjects have a purple tag, whilst statements linked to a small number of subjects have an amber tag. The clinical subjects within this group are: Cariology, Periodontology, Endodontology, Paediatric Dentistry, Preventive Dentistry, Conservative Dentistry, Prosthetic Dentistry, Orthodontics, Oral and Maxillofacial Surgery, Oral Medicine and Pathology, Oral and Maxillofacial Radiology and Imaging, Oral Implantology, Special Care Dentistry, Dental Public Health and Community Dentistry.

Discussion

This research explores strategies for embedding ES within an existing OHP curricula and the content that should be included – The 'how to do it' and 'what to include'. The output provides a complementary addition to previous reports that establish a need to embed ES in curricula and detail specific learning outcomes [13,14]. The approaches used are grounded in the evidence-base and collaboration with key stakeholders within OHP education. Key themes have been developed from academic staff and student focus groups and evidence-based statements have been mapped to all curriculum subjects. These findings apply to OHP education at all levels, across all professions and extend from junior students to professional development of qualified clinicians. It is envisaged that the strategies, the evidence-based subject-specific statements and the supporting examples are to be applied directly as appropriate within local contexts.

Normalising the topic of Environmental Sustainability to support attitude and behaviour change

Academic staff and students perceived the topic of ES to be mostly unexplored within the curriculum, with limited discussion of the topic in their previous educational experiences. A key step outlined by the two cohorts was to discuss ES frequently and to 'normalise' the topic as a key part of OHP education. This is also a key strategy outlined in the literature [34,61]. A change of mindsets is required (namely attitudes and behaviours) by all stakeholders to reinforce this key topic in all aspects of education. Students felt that there is a particular need for role models to demonstrate positive environmental attitudes and behaviours within the constraints of current clinical practice.

Environmental Sustainability transcends all disciplines of dentistry and oral healthcare

This research identified that climate change and ES are concerns that must be embedded across *all* subjects and disciplines of dentistry and oral healthcare. Previous guidelines have supported a move away from standalone ES courses delivered at a specific point in the curriculum, although it is not clear if this is a common approach [13,14,25]. Standalone ES courses do not typically extend across all curriculum subjects, do not reinforce longitudinal learning and may be more difficult to embed within an existing curriculum as it requires the creation of a new programme of study. Longitudinal interweaving of ES with horizontal and vertical integration allows for incremental learning of this challenging construct with increasing levels of sophistication and complexity and adequate coverage of all curriculum subjects [87–90]. Delivering ES education that is packaged and explored across multiple learning events and disciplines presents some important advantages. Firstly, the core learning concept will be captured and better understood if delivered in the actual context of the discipline (e.g. N_2O inhalation sedation in Paediatric Dentistry and the environmental impacts associated with this). The cumulative cognitive load will also be reduced, which may improve knowledge retention and facilitate reflection in action [28,91,92]. Whilst not specifically termed as 'cognitive load', students who participated in the focus groups raised concerns regarding additional content in an already demanding curriculum and suggested that new ES content is delivered as part of other topics. In addition to the educational benefits, it is likely this approach will reduce curriculum burden through incorporation of ES within *existing* educational events.

Baseline knowledge transmission with relevant practical application

Academic staff and students were aligned in their opinions with regards to the need for early didactic and theoretical learning of the core issues relating to climate change, the environmental impact of oral

Table 2
A list of the content statements grouped thematically with supporting content and evidence.

	Content Statement	Supporting Content	Evidence
	Raise Awareness		
A1	**The delivery of oral healthcare is often environmentally unsustainable. We need to take responsibility as a profession to mitigate these impacts.**	○ Many patients travel to dental practices, mostly by car. ○ Oral healthcare provision is not centralised but spread throughout thousands of small dental practices.	[10,11,31-33]
A2	**The environmental impacts of oral healthcare cannot be eliminated but they can be significantly mitigated.**	○ Non-centralised care is not good from an ES perspective, as distribution of goods, staff commute, waste collection and disposal are multiplied many times. ○ A significant part of oral healthcare is interventive, with reparative treatment for the management of preventable disease. This requires many patient appointments, with an associated use of energy (electricity and water), materials, PPE and waste generation. ○ All equipment, sundries and materials are part of a wasteful linear economy with a significant carbon footprint. ○ Every human activity, whatsoever its nature, has an environmental impact. ○ The best way to mitigate the environmental impacts from oral healthcare is through a reduction of the 'need to treat'. A reduction of a need to treat, is achieved through the prevention of preventable diseases and the delivery of high-quality care. ○ A reduction of 'need to treat' results in a reduced need to use resources, energy and waste generation at all points of the oral healthcare supply chain.	[15,16,33-36]
A3	**The provision of professionally delivered oral healthcare results in significant environmental impacts from: (i) Staff commute and patient travel; (ii) the product supply chain and management of waste from the dental practice.**	○ These environmental impacts are inversely related to the oral health and disease risk status of the individual. ○ That is, good oral health equates to minimal environmental impacts. ○ Good oral health requires fewer operative interventions, with a consequential reduction of all environmental impacts (Staff commute and patient travel; as well as the manufacturing, distribution and waste management of materials and sundries used in the dental practice.)	[10-12,15,31-33, 37-43]
A4	**Personal oral hygiene regimes have inevitable 'baseline' environmental impacts. These impacts arise from the product supply chain and disposal of oral hygiene products and devices.**	○ Environmental impacts that arise from effective personal care preventive regimes are an inevitable consequence of maintaining good oral health. ○ The impacts from the use of personal products and devices (e.g. toothbrush, dentifrice, interdental cleaning aids, mouthwashes) are much lower than that from the delivery of professional interventive care. Principally, because the patient is not travelling to a remote location (dental practice) and the number of these home-care products is significantly so much smaller than those used in a dental practice. ○ The paradigm between the ES impacts from dental practice and home care is a good example of why the impacts cannot be eliminated and can only be mitigated.	[12,44,45]
A5	**It is imperative to promote and maintain good oral health through the prevention of oral diseases. An effective preventive regime carries an environmental burden that is much smaller than a disease-driven interventive treatment approach.**	○ Prevention of preventable diseases and conditions including dental caries, periodontal disease, pulpal disease, tooth surface loss and oral cancers. ○ Follow evidence-based guidelines for professional delivery of oral healthcare and the promotion of personal oral health regimes. UK and European examples include: ○ NICE guidelines for recall intervals based on oral disease risk. ○ Delivering Better Oral Health: an evidence-based toolkit for prevention. ○ EFP guidelines on the clinical management of stage I-III periodontitis.	[12,38-40,42-48]
A6	**There is a need to influence and educate the profession and the public on strategies to mitigate the environmental impacts of oral healthcare.**	Staff and patient engagement through a series of proactive approaches that may include: ○ A strong focus on patient engagement and ownership of own oral healthcare, with an emphasis on home-based personal preventive regimes. ○ The conduct, and promotion and delivery of quality care that is evidence driven. ○ In-house staff training on ES, as a part of normal professional development. ○ ES champions in the dental practice and local professional communities. ○ External continuing professional development activities. ○ Patient information leaflets, promotion through social media. ○ Integration of ES messages into all aspects of oral healthcare. ○ Emphasise that the provision and maintenance of good oral health is good for the patient, good for society and the single best way of mitigating environmental impacts from oral healthcare.	[13-15,25,49-57]

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Table 2 (*continued*)

	Content Statement	Supporting Content	Evidence
A7	**The single most effective strategy to improve environmental sustainability in oral healthcare is through disease prevention. This will result in less travel, less use of resources and less waste generation.**	○ Promote effective preventive strategies for all patients, tailored to their age and needs. ○ Reduce frequency and consumption of sugars and acidic drinks. ○ Promote toothbrushing and fluoridation. ○ Encourage dental attendance and risk-based maintenance schedules. ○ Promote a reduction in alcohol consumption and tobacco cessation. ○ Adopting a minimal intervention approach to oral healthcare. ○ Where appropriate and feasible, water fluoridation should be considered as a community approach for the prevention of caries.	[12,15,34,38,42,43,49,53,58]
Behaviour Change			
B1	**Environmental sustainability requires a culture change across the profession and supply chain.**	○ Normalise the subject of ES. ○ Start with informal discussions to increase awareness and increasingly formalise into organisational/practice protocols and procedures (e.g. designate sustainability leads). ○ Translating personal, home-based attitudes and behaviours to the professional setting. ○ Apprehension and resistance to ES behaviour changes, can be overcome by *increasing awareness and identifying common ground and strength of feelings amongst colleagues*.	[15,16,31,34,55,59-62]
B2	**Communicating effective and evidence-based prevention will benefit patients' oral health and mitigate environmental impacts.**	○ Increase patient awareness on the impact that good oral health has on them, society and the environment. ○ Motivate patients to take greater ownership for their own oral health, with an emphasis on home-based personal preventive regimes. ○ Support patients to embed new oral health behaviours when they are ready to do so. ○ Patients as co-creators and co-managers of their oral health. ○ Increase patient awareness on the importance of preventive regimes that are tailored to their age and needs.	[15,47,53]
B3	**The formulation of action plans and policies will result in more environmentally sustainable practice.**	○ Designate a lead sustainability officer or dental practice champion or a sustainability working group. ○ Add sustainability to the practice agenda and ethos. ○ Foster an inclusive environment where staff can exchange ideas on ways to do things better.	[15,53,63]
B4	**Avoid waste: high-quality and efficient patient care will mitigate environmental impacts.**	○ Only use what is necessary by planning each patient encounter. ○ Focus on high-quality care by using fit for purpose materials and instruments that are grounded in evidence-based techniques.	[34,64,65]
4 R's – Reduce, Reuse, Recycle, Rethink			
C1	**Delivering a prevention-focused, patient-centred high quality oral health care service will reduce treatment need and the resultant environmental impact.**	○ The best way to mitigate the environmental impacts from oral healthcare provision is through a reduction of the 'need to treat'. A reduction of a need to treat, is best achieved through the prevention of preventable diseases and the delivery of high-quality care. ○ A reduction of 'need to treat' results in a reduced need to use resources, energy and waste generation at all points of the oral healthcare supply chain.	[12,34-36]
C2	**Consider using reusable options where appropriate.**	○ Use of cloth fabric alternatives to SUPs including clothes, barriers and cleaning items. ○ Reusable PPE: laboratory coats to replace aprons, reusable face shields, patient bibs. ○ Use of washable cups, dishes and cutlery. ○ Reusable instruments (impression trays, suction tips, matrix band retainers).	[15,37,39,40,51,66-68]
C3	**A shift from a wasteful linear economy to a more sustainable circular economy in oral healthcare is possible by proactively seeking and implementing recycling opportunities.**	○ Educate staff about recycling in all areas of the dental practice. ○ Enable waste separation/segregation for ease of recovery for recycling. ○ Improve awareness and liaising with local authorities and support groups. ○ Identify and use pre-existing community recycling programmes to recycle separated paper and plastic parts of autoclavable bags and packaging. ○ Recycle office waste such as plastics, paper and medical shredding, printer cartridges.	[15,35,60,65,69-71]
C4	**Rethink - how can you optimise existing systems and processes to be more environmentally sustainable?**	○ Use of digital technology for patient appointments, records, electronic reminders. ○ Electronic credit card transfers and order forms. ○ Reduce paper use. ○ Engage with emerging scientific/technological changes to the profession.	[15,31,72]
Good Quality Oral Healthcare			

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Table 2 (*continued*)

	Content Statement	Supporting Content	Evidence
D1	**Good oral healthcare is good for the patient, good for the profession and good for the environment.**	○ Delivery and maintenance of good oral health, focused on prevention and with the provision of durable interventions, using high quality products materials and that will last longer and/or require fewer revisions. ○ Careful planning and execution of clinical procedures should lead to a reduction of materials and equipment use.	[12,34]
D2	**A reduction in the need for professional-led interventions is achieved through disease prevention. This is the single most environmentally sustainable measure.**	○ The best way to mitigate the environmental impacts from oral healthcare provision is through a reduction of the 'need to treat'. A reduction of a need to treat, is best achieved through the prevention of preventable diseases and the delivery of high-quality care. ○ A reduction of 'need to treat' results in a reduced need to use resources, energy and waste generation at all points of the oral healthcare supply chain. ○ The provision of oral healthcare in all settings should focus on the fundamental messages of oral health promotion and disease prevention: ○ Effective preventive strategies for all patients, adapted to their age and needs. ○ Reduction in the frequency and consumption of sugars and acidic drinks. ○ Encourage toothbrushing and fluoridation. ○ Encourage dental attendance and risk-based maintenance schedules. ○ Promote a reduction in alcohol consumption and use of and cessation of tobacco products.	[12,15,18,34,35,49,58]
D3	**High quality operative care reduces repair, replacement and waste.**	○ Adopting evidence-based practices to achieve high-quality and durable clinical outcomes. ○ Establish protocol-driven patient-care practices to drive reproducibility of high-quality and durable outcomes. ○ Careful selection and use of dental materials, instruments and equipment in accordance with the manufacturer's 'Directions for Use'.	[18,34]
D4	**Integrated healthcare services with patients as co-managers of their care mitigates environmental impacts.**	○ Structured treatment plans that are professional led with joint 'patient-professional' responsibility for delivery. ○ Support patients to be co-managers of their oral healthcare: Active participation in decision-making, treatment and maintenance. ○ Smart treatment planning to reduce the number of appointments. ○ Integration with wider healthcare services to facilitate a multi-disciplinary approach to patient care.	[18,34]
D5	**There is a need to take ownership of the care that you provide through lifelong learning to deliver high quality clinical outcomes. Evidence-based procedures provide environmentally sustainable care.**	○ A professional that maintains knowledge and skills to a high standard is well placed to provide good quality care. ○ Good quality care is environmentally sustainable care. ○ Learn and develop best practice: pursue a tailored programme of continued professional development (CPD). ○ Lead by example: set high standards, engage with the profession, make a difference, inspire others. ○ Effective clinical governance: review, reflect and improve the quality of care you provide. ○ Engage with local networks, national organisations and practice-based research.	[18,34]
Knowledge Exchange - Research			
E1	**Developing a research curiosity will increase your levels of knowledge and awareness and may help to mitigate the environmental impacts of oral healthcare.**	○ Be aware and have knowledge of important environmental research methodologies including Life Cycle Assessments (LCA). ○ Identify and select high quality evidence that considers clinical effectiveness but also economic feasibility and environmental sustainability. ○ Use current and strong evidence-based knowledge to guide your decision making at all stages of care.	[14]
E2	**Evidence-based dentistry must consider the triple bottom line of clinical effectiveness, cost effectiveness and environmental sustainability.**		[38,73]
E3	**It is important to guard against misinformation and disinformation that may influence the objectivity of your decision-making.**	○ There is confusion, misinformation and disinformation in environmental sustainability that is influenced by the media and individual opinion. ○ Adopt a critical approach to all literature to avoid nonfactual and harmful information and agendas.	[17]
Policy and Regulations			
F1	**Active engagement with environmental policies and regulations in oral healthcare will mitigate your environmental impact.**	○ Engage with effective Antibiotic Stewardship. ○ Follow current regulations to handle, manage and dispose of dental amalgam safely. ○ Adopt evidence-based clinical care guidelines to determine patient care pathways and follow up appointments. E.g. Delivering Better Oral Health, NICE guidelines on recall intervals, European Federation of Periodontology guidelines.	[46-48,74,75]

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Table 2 (*continued*)

	Content Statement	Supporting Content	Evidence
F2	**Active engagement and collaboration with policymakers will lead to the development of more environmentally sustainable oral healthcare policies.**	○ Promote innovative ways to maintain high quality care delivery whilst mitigating environmental impacts. ○ Engage with municipal waste management and collection services to further mitigate impacts. E.g. waste separation, recycling, energy recovery incineration. ○ Challenge the status quo at a local level, within the workplace e.g. laboratories, reception, common room, waste segregation.	[15,76]
	Environmental Impact - Travel		
G1	**Adopting more sustainable travel options will mitigate your environmental impact.**	○ Promote and encourage active travel (such as walking and cycling) where possible. ○ Encourage the use of public transport and car sharing when active travel not feasible. ○ Encourage and facilitate electric vehicle use amongst colleagues.	[15,56,59,64,65]
G2	**Planning patient care to reduce the number of appointments will mitigate the environmental impact of the care you provide.**	○ Reduce the number of appointments by providing multiple procedures in one visit. ○ Engage with Tele-dentistry and Remote Clinical Consultations to reduce travel. ○ Combine family appointments wherever possible. ○ Using digital technologies (CAD-CAM, intra-oral scanning, 3D printing) will reduce the number of appointments and transport to dental laboratories.	[15,53,56,59,64,65,72]
G3	**Facilitating care delivery in multi-professional health centres will mitigate the environmental impact of the care you provide.**	○ Engage with oral health outreach programmes where only the OHP team travels. An example is Childsmile with reduced travel, carbon emissions and improved air quality. ○ Provision of on-site preventive care facilities in nursing and care homes. ○ Centralised resources, procurement, waste management and circularity.	[34,38,42,43,64]
G4	**Optimising dental practice administration will mitigate the environmental impact of the care you provide.**	○ Optimise efficiency of transport between the clinic and the dental laboratory. ○ Increased use of telecommunication for all administrative logistics (eg. SMS reminders, virtual post-op follow ups). ○ Effective scheduling to allow appointments with different OHPs on the same day.	[15,59,64,72]
	Environmental Impact – Procurement		
H1	**Procured goods have an inherent environmental impact that arises from the supply chain. This is additional to clinical or consumer use and includes: sourcing of raw materials - manufacturing - packaging - distribution - procurement - waste management.**	○ All procured oral health items reach the consumer or the dental practice with a large 'pre-loaded' environmental impact tag – Purchased goods accumulate environmental impacts in an incremental manner as the product moves from one stage to the next along the supply chain. ○ Purchase durable equipment that have long warranties and are easy to maintain. ○ During the procurement process, consider the energy use in the distribution/delivery of the product and the management of waste with special consideration to the product presentation and packaging used. ○ Optimise how products are sourced through effective stock management, waste auditing, purchasing bulk deliveries and selecting products with minimal packaging.	[15,16,31,65,76,77]
H2	**Engaging and challenging stakeholders across the supply chain will support environmentally sustainable practices.**	○ Work and engage with suppliers to assess their sustainability practices. ○ Apply pressure to suppliers to engage to act in an environmentally sustainable manner. ○ Request recycling information for medical equipment from manufacturers. ○ Identify locally produced items and coordinate with local suppliers to reduce travel. ○ Reducing and reusing packaging.	[15,16,53,55]
H3	**Selecting fit for purpose dental materials, clinical items (PPE and products) and equipment will mitigate the environmental impacts of the care you provide.**	○ Adopt a prevention-first approach to reduce oral healthcare interventions, material use and associated environmental impact. ○ Use high-quality materials and follow clinical guides to optimise restoration longevity. ○ Proactively reduce the use of amalgam in line with the Minamata Convention to phase down and phase out the use of amalgam in clinical dental practice. ○ Critically evaluate the environmental impact of all dental materials and incorporate this into decision-making at all levels. ○ Follow the Directions for Use (DFUs) very carefully for each material system for correct and optimum clinical outcomes.	[34,77]
	Environmental Impact – Energy and Water Consumption		
I1	**Reducing energy and water consumption at all levels of oral healthcare is key to mitigating the environmental impacts of oral healthcare.**	○ Use energy efficient appliances (e.g. LED, fluorescent bulbs, light sensors, dimmer switches). ○ Make use of natural lighting and turn off the lights when not in use. ○ Turn off the tap when brushing. ○ Use appliances when fully loaded. ○ Maintain and upgrade boilers and air conditioning units to ensure they are energy efficient.	[15,36,51,55,59,65,78,79]

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Table 2 (*continued*)

	Content Statement	Supporting Content	Evidence
		○ Better use of windows and blinds to regulate temperature before using air conditioning.	
I2	**The use of energy from renewable sources will mitigate your environmental impacts.**	○ Produce your own renewable energy through use of solar panels, wind turbines, solar thermal systems, and heat pumps. ○ Engage with energy companies that use renewable energy.	[15,36,55,65,78-80]
Environmental Impact – Waste Management			
J1	**Developing and implementing a local environmentally sustainable waste management plan will mitigate your environmental impacts.**	○ Implementation of the 4 Rs (reduce, reuse, recycle, rethink). ○ Identify and use effective waste disposal services that are close to the practice. ○ Incorporate the management of food waste, consider energy conversion or composting. ○ Waste segregation. ○ Use licensed handlers for off-site recycling of hazardous materials. ○ Use incineration facilities with energy recovery where possible.	[15,53,68,70]
J2	**Engaging and challenging all stakeholders will result in more environmentally sustainable waste disposal procedures.**	○ Increase awareness of waste management and the associated costs. ○ Ensure effective waste segregation. ○ Ensure that waste contractors are complying with the appropriate local and national legislation at all levels, from collection to disposal. ○ Encourage contractors to diversify to include novel recycling opportunities.	[15,53]
J3	**Reducing medicinal waste through evidence-based prescribing will mitigate the environmental impacts of the care you provide.**	○ Only prescribe the required amount and dose. ○ Follow evidence-based national/international prescribing guidelines. ○ Adopt antibiotic stewardship to promote and monitor judicious use of antimicrobials. ○ Encourage patients to return unused medication to the pharmacy for safe disposal ○ Discourage disposal down sink or toilet as this has a huge impact on biodiversity and antibiotic resistance.	[15,65,68,74,75]
J4	**Reducing and recycling plastic waste will mitigate the environmental impacts of the care you provide.**	○ Conduct environmental audits of the dental practice following the principles of the International Chamber of Commerce. ○ Minimise single use plastics as much as possible and replace with reusable items including matrix band retainers, anaesthetic syringes, aspiration tips, Dappen's pots. ○ Adopt reusables where possible to reduce single use plastic waste.	[33,68,81-83]
Dental Materials			
K1	**Managing amalgam waste through safe practices will mitigate the environmental impacts of the care you provide.**	○ Use water-spray and high-volume aspiration when removing amalgam restorations. ○ Use effective chairside traps, vacuum filters, amalgam separators that meet ISO 11143. ○ Avoid the use of hypochlorite cleaners, as they increase dissolution of mercury. ○ Have an amalgam spill-kit for manage elemental mercury. ○ Recycle waste amalgam with effective collection, separation and recovery of mercury and silver through approved biological waste management companies.	[15,51,53,68-71,84,85]
K2	**Reducing the use of nitrous oxide will mitigate the environmental impacts of the care you provide.**	○ Reduce the need for inhalation sedation through high-quality preventive oral healthcare thus avoiding operative interventions and other forms of sedation and anaesthesia. ○ Capture and neutralise the gas during use. ○ Use effective protocols and standard operating procedures to avoid atmospheric pollution.	[15,59,60]
K3	**Reducing gypsum use for dental casts will mitigate the environmental impacts of the care you provide.**	○ Employ intra-oral scanning to reduce impression material and gypsum waste. ○ Consider 3D printing and biodegradable resins to produce models. ○ Adopt biodegradable alternatives to gypsum. ○ Consider recycling options for gypsum.	[15,56,66,69,71]
K4	**Recovering and recycling dental materials, clinical items (PPE and products) and equipment will mitigate the environmental impacts of the care you provide.**	○ Recycle waste amalgam, gypsum, lead foil, metal used in fixed/removable prosthodontics. ○ Segregate and recycle sterile packaging. ○ Use surgery zoning to separate contaminated and non-contaminated waste and facilitate recycling of these items where possible.	[15,65,70]
K5	**Using digital radiography will mitigate the environmental impacts of the care you provide.**	○ Reduced use of harmful silver thiosulphate fixer. ○ Reduction of lead foil waste. ○ Improved image quality, reduced radiation exposure, editing abilities, facilitated storage & access.	[15,51,66,69,85]
K6	**Using environmentally sustainable disinfectant procedures will mitigate the environmental impacts of the care you provide.**	○ Use of ultrasonic, steam or dry heat for sterilisation instead of more toxic cleaning agents. ○ Avoid disposal of toxic pollutant solutions into the municipal wastewater sewerage system.	[39,51,59,66,86]

Table 3
Content statements and curriculum subject mapping results.

Code	Content Statements	Subject Applicability
	Raise Awareness	
A1	**The delivery of oral healthcare is currently environmentally unsustainable. We need to take responsibility as a profession to mitigate these impacts.**	Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
A2	**The environmental impacts of oral healthcare cannot be eliminated but they can be mitigated.**	Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
A3	**The provision of professionally delivered oral healthcare results in significant environmental impacts from: (i) Staff commute and patient travel; (ii) the product supply chain and management of waste from the dental practice.**	*ALL clinical subjects*
A4	**Personal oral hygiene regimes** have inevitable 'baseline' **environmental impacts. These impacts arise from the product supply chain and disposal of oral hygiene products and devices.**	*ALL clinical subjects* Less relevant to: Endodontology, Oral and Maxillofacial Radiology
A5	**It is imperative to promote and maintain good oral health through the prevention of oral diseases. An effective preventive regime carries an environmental burden that is much smaller than a disease-driven interventive treatment approach.**	*ALL clinical subjects* Less relevant to: Oral and Maxillofacial Radiology
A6	**There is a need to influence and educate the profession and the public on strategies to mitigate environmental impacts of oral healthcare.**	*ALL clinical subjects* and Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
A7	**The single most effective strategy to improve environmental sustainability in oral healthcare is through disease prevention. This will result in less travel, less use of resources and less waste generation.**	*ALL clinical subjects*
	Behaviour Change	
B1	**Environmental sustainability requires a culture change across the profession and supply chain.**	Dental Public Health & Community Dentistry, Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management
B2	**Communicating effective and evidence-based prevention will benefit** patients' oral health and mitigate environmental impacts.	*ALL clinical subjects* and Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
B3	**The formulation of action plans and policies will result in more environmentally sustainable practice.**	Dental Practice Management
B4	**Avoid waste: high-quality and efficient patient care will mitigate environmental impacts.**	*ALL clinical subjects* and Dental Technology, Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management
	4 Rs – Reduce, Reuse, Recycle, Rethink	
C1	**Delivering a prevention-focused, patient-centred high quality oral health care service will reduce treatment need and the resultant environmental impact.**	*ALL clinical subjects*
C2	**Consider using reusable options where appropriate.**	*ALL clinical subjects* and Basic Sciences, Dental Technology, Dental Practice Management
C3	**A shift from a wasteful linear economy to a more sustainable circular economy in oral healthcare is possible by proactively seeking and implementing recycling opportunities.**	Basic Sciences, Dental Practice Management
C4	**Rethink - how can you optimise existing systems and processes to be more environmentally sustainable?**	Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management
	Good Quality Oral Healthcare	
D1	**Good oral healthcare is good for the patient, good for the profession and good for the environment.**	*ALL clinical subjects* and Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
D2	**A reduction in the need for professional-led interventions is achieved through disease prevention. This is the single most environmentally sustainable measure.**	*ALL clinical subjects* Less relevant to: Oral and Maxillofacial Radiology
D3	**High quality operative care reduces repair, replacement and waste.**	*ALL clinical subjects* and Dental Technology
D4	**Integrated healthcare services with patients as co-managers of their care mitigates environmental impacts.**	*ALL clinical subjects* and Dental Technology
D5	**There is a need to take ownership of the care that you provide through lifelong learning to deliver high quality clinical outcomes. Evidence-based procedures provide environmentally sustainable care.**	*ALL clinical subjects* and Dental Technology, Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management

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Table 3 (*continued*)

	Knowledge Exchange - Research	
E1	**Developing a research curiosity will increase your levels of knowledge and awareness and may help to mitigate the environmental impacts of oral healthcare.**	Basic Sciences, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
E2	**Evidence-based dentistry must consider the triple bottom line of clinical effectiveness, cost effectiveness and environmental sustainability.**	*ALL clinical subjects* and Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
E3	**It is important to guard against misinformation and disinformation that may influence the objectivity of your decision-making.**	Basic Sciences, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences
	Policy and Regulations	
F1	**Active engagement with environmental policies and regulations in oral healthcare will mitigate your environmental impact.**	*ALL clinical subjects* and Dental Biomaterials, Dental Technology, Ethics, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management
F2	**Active engagement and collaboration with policymakers will lead to the development of more environmentally sustainable oral healthcare policies.**	Dental Public Health and Community Dentistry, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management
	Environmental Impact - Travel	
G1	**Adopting more sustainable travel options will mitigate your environmental impact.**	Core Environmental Sustainability learning and teaching events, extra-curricular culture change.
G2	**Planning patient care to reduce the number of appointments will mitigate the environmental impact of the care you provide.**	Dental Practice Management
G3	**Facilitating care delivery in multi-professional health centres will mitigate the environmental impact of the care you provide.**	*ALL clinical subjects* and Dental Practice Management
G4	**Optimising dental practice administration will mitigate the environmental impact of the care you provide.**	Dental Practice Management
	Environmental Impact - Procurement	
H1	**Procured goods have an inherent environmental impact that arises from the supply chain. This is additional to clinical or consumer use and includes: sourcing of raw materials - manufacturing - packaging - distribution - procurement - waste management.**	Core Environmental Sustainability learning and teaching events, extra-curricular culture change.
H2	**Engaging and challenging stakeholders across the supply chain will support environmentally sustainable practices.**	Basic Sciences, Dental Public Health and Community Dentistry, Professionalism, Information Literacy, Social Accountability and Behavioural Sciences, Dental Practice Management
H3	**Selecting fit for purpose dental materials, clinical items (PPE and products) and equipment will mitigate the environmental impacts of the care you provide.**	*ALL clinical subjects* and Dental Biomaterials, Dental Technology, Dental Practice Management
	Environmental Impact – Energy and Water Consumption	
I1	**Reducing energy and water consumption at all levels of oral healthcare is key to mitigating the environmental impacts of oral healthcare.**	*ALL clinical subjects* and Basic Sciences, Dental Biomaterials, Dental Technology, Dental Practice Management
I2	**The use of energy from renewable sources will mitigate your environmental impacts.**	Dental Practice Management
	Environmental Impact – Waste Management	
J1	**Developing and implementing a local environmentally sustainable waste management plan will mitigate your environmental impacts.**	Basic Sciences, Dental Practice Management
J2	**Engaging and challenging all stakeholders will result in more environmentally sustainable waste disposal procedures.**	Basic Sciences, Dental Public Health and Community Dentistry, Dental Practice Management
J3	**Reducing medicinal waste through evidence-based prescribing will mitigate the environmental impacts of the care you provide.**	*ALL clinical subjects* and Basic Sciences (specifically Microbiology and Pharmacology)
J4	**Reducing and recycling plastic waste will mitigate the environmental impacts of the care you provide.**	*ALL clinical subjects* and Basic Sciences, Dental Biomaterials, Dental Technology, Dental Practice Management
	Dental Materials	
K1	**Managing amalgam waste through safe practices will mitigate the environmental impacts of the care you provide.**	Cariology, Conservative Dentistry, Prosthetic Dentistry, Special Care Dentistry, Dental Public Health and Community Dentistry, Dental Biomaterials, Dental Practice Management
K2	**Reducing the use of nitrous oxide will mitigate the environmental impacts of the care you provide.**	*ALL clinical subjects* Less relevant to: Orthodontics, Oral and Maxillofacial Radiology
K3	**Reducing gypsum use for dental casts will mitigate the environmental impacts of the care you provide.**	*ALL clinical subjects* and Dental Technology Less relevant to: Endodontology, Preventive Dentistry, Oral Medicine and Pathology, Oral and Maxillofacial Radiology
K4	**Recovering and recycling dental materials, clinical items (PPE and products) and equipment will mitigate the environmental impacts of the care you provide.**	*ALL clinical subjects* and Dental Technology, Dental Practice Management
K5	**Using digital radiography will mitigate the environmental impacts of the care you provide.**	Oral and Maxillofacial Radiology and Imaging, Oral Medicine and Pathology, Dental Practice Management
K6	**Using environmentally sustainable disinfectant procedures will mitigate the environmental impacts of the care you provide.**	Dental Practice Management

healthcare and the need to overcome existing barriers and strategies to achieve environmentally sustainable change. It was widely acknowledged that students come from diverse backgrounds and current pre-university education does not provide a standardised approach to environmental science. The delivery of 'baseline' didactic teaching through lectures or other feasible methods is valuable to achieve standardised learning prior to further subject (ES) exploration across the multiple disciplines within the OHP curriculum. The FDI World Dental Federation has recently published a Massive Open Online Course (MOOC) to help professionals and students to understand the importance of sustainable practices and their own role in championing environmental sustainability within oral healthcare [17]. The importance of relevant practical application of theoretical learning was discussed amongst both cohorts and this aligns with the need for both conceptual and experiential knowledge [93]. A disparity between these two knowledge systems results in a 'theory-practice' gap and a lack of practical emphasis may lead to a perception that ES is not importance or actionable [94].

Viewing and modifying existing teaching and assessment events through a different lens

It is extremely positive that academic staff and students identified multiple opportunities to modify existing teaching and assessments events by adapting the lens in which we view OHP education. Both cohorts raised suggestions regarding modifying existing teaching content, learning resources, clinical systems, and assessment rubrics. These relatively simple changes will convey several important benefits: normalise ES, incorporate ES across the full length of the curriculum and incorporate ES within assessments. Specific ideas include incorporating ES into current lectures, adapting clinical forms and awarding marks for ES in clinical and written assessments.

Safeguarding against misinformation and disinformation

Climate change and ES are emotive topics and academic staff and students must be conscious of the risk of eco-anxiety and the need to provide appropriate student support measures [95]. Such measures may include an open discussion staff-student forum where issues can be voiced and addressed in an objective, balanced and informed manner. Misinformation and disinformation can exacerbate levels of eco-anxiety, which must be avoided. Environmental sustainability is a pragmatic approach to the mitigation of environmental impacts that is grounded in an evidence-based approach. Awareness of emerging environmental research methods including life-cycle assessment (LCA) is essential.

ES is sometimes erroneously linked to other polarised attitudes and behaviours that can serve as strong detractors and demotivators to employing more sustainable oral healthcare. As professionals and educators, we should guard against and protect others from, these disinformation messages. A careful use of resources and approaches that are grounded in sound science must be employed across all levels of OHP education.

Using the evidence-based and subject-specific content statements

The content statements proposed in this paper have been developed from an extensive evidence base and have been mapped across nineteen curriculum subjects throughout the length of the OHP curriculum. It is unusual for educational content to be developed as a direct aim of a research investigation. Educators usually develop content that is informed by current and robust research in the field that is combined with their own expertise and experiences. However, a significant barrier to embedding ES in OHP and wider healthcare curricula is educator unfamiliarity with the topic and a lack of practical guidance [21,22,96-99]. It is envisaged that this research will help to overcome this barrier by providing educators with evidence-based subject-specific statements that can be incorporated directly into their teaching – across any discipline.

The statements may be taken directly or modified according to the educator's expertise and the curriculum event it will be incorporated into. Additionally, the statements may be used in isolation, or if educators feel more detail is needed, the additional content column in Table 2 may be used to provide further information and examples. Table 4 presents examples of how the statements can be used in different areas of teaching. These statements could be included to augment existing teaching, perhaps through an additional slide to a lecture, or incorporated into clinical learning material.

The consultation process with discipline experts established that some statements can be further adapted to the curriculum subject. The aim of this research is to provide statements that serve as a baseline message grounded in scientific evidence. Further modification by discipline experts is expected as educators become more comfortable in embedding ES in their teaching. An example of some statements being tailored to individual disciplines can be found in Table 5.

The ES content and messages identified in this work are designed to be clear and succinct. Notwithstanding, we recognise that their application to complex clinical management scenarios may be less clear and require a patient-centred critical decision-making process. In these cases, ES gains for different clinical management approaches must be carefully weighed up against each other and against the care needs for the patient. In any event, it is important to establish the educational principle that the default baseline setting for the management of a condition is always set by any robust evidence-based guidance or recommendations that are accepted by a recognised professional body. An example of this scenario is the clinical management of pericoronitis. The recurrent nature of the condition may require multiple patient visits that

Table 4
Examples of the use of evidence-based statements in a variety of teaching topics.

Teaching Topics	Evidence-based Content Statement(s) to be incorporated
Prevention of Oral Cancer	It is imperative to promote and maintain good oral health through the prevention of caries, periodontal disease, pulpal disease and oral cancers. An effective preventive regime carries an environmental burden, but this is much smaller than a disease-driven interventive treatment approach. We can mitigate the environmental impact of oral healthcare through effective preventive strategies.
Operative Management of Dental Caries	High quality operative care reduces repair, replacement and waste. Using fit for purpose dental materials and following evidence-based procedures will help to provide environmentally sustainable care and long-lasting clinical outcomes.
Antimicrobial Resistance	Reducing medicinal waste through evidence-based prescribing will mitigate the environmental impacts of the care you provide. Active engagement with environmental policies and regulations in oral healthcare will mitigate your environmental impact.
Sedation in Paediatric Dentistry	The single most effective strategy to improve environmental sustainability in oral healthcare is through disease prevention. This will result in less travel, less use of resources and less waste generation. Reducing the use of nitrous oxide will mitigate the environmental impacts of the care you provide.
Digital Radiography	Using digital radiography will mitigate the environmental impacts of the care you provide.

Table 5
Examples of further modifications to content statements when mapped to individual curriculum subjects.

Original Statement	Subject	Modified Statement
It is imperative to promote and maintain good oral health through the prevention of caries, periodontal disease, pulpal disease and oral cancers. An effective preventive regime carries an environmental burden, but this is much smaller than a disease-driven interventive treatment approach. We can mitigate the environmental impact of oral healthcare through effective preventive strategies.	Oral Medicine and Pathology	It is imperative to promote and maintain good oral health through the prevention of oral cancers. An effective preventive regime carries an environmental burden, but this is much smaller than a disease-driven interventive treatment approach such as tumour resection. We can mitigate the environmental impact of oral healthcare through effective preventive strategies and early identification and referral.
Selecting evidence-based fit-for-purpose materials, instruments, equipment and sundries will mitigate the environmental impacts of the care you provide.	Dental Biomaterials	Selecting evidence-based fit-for-purpose dental materials will mitigate the environmental impacts of the care you provide.
The single most effective strategy to improve environmental sustainability in oral healthcare is to focus on disease prevention. This will result in less travel, resource use and waste generation.	Paediatric Dentistry	The single most effective strategy to improve environmental sustainability in oral healthcare is to focus on disease prevention. This will reduce a lifetime of oral disease burden and will result in less travel, resource use and waste generation.
Aligned and integrated healthcare services with patient co-management of care mitigates environmental impacts.	Dental Public Health and Community Dentistry	Aligned and integrated oral healthcare services, including its commissioning, contracting, and monitoring, should consider their environmental impact.

have to be balanced against the carbon footprint of its management. Clinicians should follow the accepted professional specialty guidelines [100,101]. Conservative management may include multiple patient visits to care centres, multiple treatment episodes and ongoing specific home care and maintenance regimes with more cleaning, irrigation, and chlorhexidine mouthwash. Additionally, multiple prescriptions of antibiotics may be required. Conversely, a surgical management will require local anaesthesia and potentially sedation or general anaesthesia. Each of these two approaches has its own environmental impacts from the surgical care, equipment, sterilisation, single use plastics and waste.

These investigations have achieved the aims of identifying suitable strategies to embed ES within an existing curriculum and creating evidence-based and subject-specific ES content. The focus groups included a significant number of academic staff and students and the consultation process for the evidence-based statements included views from three key stakeholders of OHP education. A potential limitation of this study is the acceptance of probable selection bias of participants within the focus groups and the consultation process. That is, despite a participant selection process that actively encouraged inclusivity and diversity of opinions; it is likely that study participants self-selected by virtue of their inherent interest in the subject. This is not necessarily considered to be a drawback in this study as the participant's interest (and bias) towards the subject enabled the acquisition of a comprehensive range of strategies and content statements for the inclusion of ES in the curriculum. Additionally, whilst the authors acknowledge that the use of flow chart is useful to present the findings of the literature searches, this was not possible due to the extensive date range of the literature search that spanned several years.

There is an acknowledgement of wide health inequalities across the world, both within countries and across borders. For the oral healthcare profession, this presents a real challenge with a need to balance preventive oral healthcare with sustainability goals [16]. Moreover, the evidence that supports our current understanding of the perceived educational challenges and the proposed solutions, arise from a relatively small number of higher education institutions [21–23]. It is important therefore, that the strategic educational approaches and content that are promoted in this document are considered in the cultural and socio-economic contextual framework of the region in which they are to be implemented.

Conclusions

There is an urgent need to include Environmental Sustainability in the education of Oral Health Professionals at all stages, from early undergraduate to postgraduate continuing professional development. This study identifies for the first time a comprehensive strategy for the inclusion and delivery of Environmental Sustainability (method and content) in the curriculum. A novel method to define and map curriculum content has been explored and validated using a range of complementary methodologies. A comprehensive and robust list of evidence-based and subject-specific educational content statements have been defined in the field of Environmental Sustainability in dentistry and oral healthcare. These statements have been mapped to all curriculum subjects and it is envisaged that these can be adopted and integrated by educators into the existing curriculum, without the need to disrupt the core syllabus and course structure.

Research data

The data from the focus groups that supports this research publication has been shared. This data can be freely downloaded from the University of Sheffield Research Data Repository at https://orda.shef.ac.uk/articles/dataset/_b_Curriculum_Content_for_Environmental_Sustainability_in_Dentistry_b_/25342006, under the terms of the Creative Commons Attribution (CC BY-NC 4.0) licence.

CRediT authorship contribution statement

Jonathan Dixon: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **James Field:** Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Emma Gibson:** Investigation, Formal analysis. **Nicolas Martin:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to acknowledge the input of all academic staff and students that participated in this research. The work by the Environmental Sustainability in Dentistry (Jasmine Webster, Thomas Marwood, Salih Gajoum, Faye Calpin and Amelia Cowie) student task team in supporting student recruitment is greatly appreciated.

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Chapter VIII – Implementing and Evaluating the Impact of a Range of Learning and Teaching Interventions for Environmental Sustainability in the Undergraduate Dental Curriculum

Introduction

Climate change is a critical global challenge that affects all societies and sectors, including Dentistry [188]. The provision of oral healthcare has a significant environmental footprint [10,11,202]. The biggest contributors to the environmental impact of oral healthcare are patient and staff travel, procurement and energy use [10]. A transition to more environmentally sustainable oral healthcare will be challenging, and the profession faces numerous barriers, including a lack of professional awareness and a high dependence on single-use plastics [11]. These challenges must be directly confronted in order to meet the ambitious goals set by governments and other stakeholders [12,188,194–196].

Environmental sustainability in dentistry (ESD) has been defined as: "*strategic, holistic and long-term approaches committed to minimising the environmental impact of activities relating to oral healthcare and Oral Health Professional education*" [20]. Providing education related to ESD at all levels has been highlighted as a critical approach to making the profession more environmentally sustainable [16], and previous research suggests that, students, staff, regulators and professional organisations agree and support the need to incorporate environmental sustainability (ES) into undergraduate dental education [13,251,270,273,274,323,326–328,328].

Undergraduate dental and oral health professional (OHP) curricula serve as a framework to outline the cumulative learning that must be achieved across the length of programmes to develop high-quality professionals. Dental curricula are complex and are usually informed by standards produced by national regulators, with the General Dental Council

acting for the United Kingdom [1,15,92]. Whilst curricula must meet the regulatory requirements within each country, they must also remain fit for the purpose in the context of a changing profession and society and meet the needs of the local population. ES is an example of an emerging topic that must be incorporated into OHP education, with national and regional bodies proposing learning outcomes across Europe [15,326]. In this context, the curriculum must be flexible to incorporate ES without deviating from the core aim - to produce high-quality OHPs.

There are limited published models or examples of how the dental curriculum develops to include emerging topics. Whilst subjects such as ethics and professionalism, which require a demonstration of attitudes, values and behaviours, have been incorporated into dental curricula over the past twenty years, there is no guidance on *how* this was achieved [105,162,164,330]. Additionally, it is unclear if providing such education has resulted in demonstrable attitude and behaviour changes. Existing models of curriculum development can be considered outdated and mainly refer to fundamental changes in curriculum philosophy [5,8,18,19]. As such, a structured and pragmatic approach is needed that considers the current context of dental and OHP education and enables *existing* curricula to develop with minimal disruption.

Numerous barriers to embedding ES in the curriculum have been reported, including a lack of curriculum space and resources to guide educators [251,323,324]. Recent research by Dixon *et al*. [323,327] provides key strategies to embed ES within an *existing* curriculum. This establishes the need for learners to acquire a baseline 'bolus' of knowledge in the early years of programmes and emphasises the importance of practical reinforcement of ES topics. This research also demonstrated that there may be numerous opportunities within the existing curriculum to *augment* teaching and assessment methods to include ES. This approach avoids developing extensive new teaching and assessment strategies for ES and overcomes the challenge associated with an overloaded curriculum.

Additionally, it is acknowledged that many educators feel they lack the expertise and knowledge to teach ES [251,323,324]. However, for ES to be considered a core part of

professional practice, the environmental aspects of dentistry must be taught alongside all clinical disciplines. Additional work by Dixon *et al*. [327] produced evidence-based and discipline-specific content statements for ESD. These serve as concise statements that can be incorporated into existing teaching events, perhaps as single or multiple slides in a lecture. These statements provide educators with evidence-based messages on ESD and should mitigate concerns regarding misinformation and a lack of knowledge. Whilst the content and strategies outlined are promising, these approaches need to be tested in a real-life context to determine whether they are effective at increasing attitudes, knowledge and awareness of ESD.

Aims and Objectives

Aim

To evaluate the effectiveness of an educational strategy that includes a range of learning and teaching events to embed environmental sustainability across the length of the undergraduate dental and oral health professional curriculum.

Objectives

- To assess baseline awareness, knowledge and attitudes toward environmental sustainability in dentistry among oral health professional students.
- To deliver a range of learning and teaching events for environmental sustainability in dentistry across the length of the undergraduate dental and OHP curriculum.
- To assess the impact of these learning and teaching events on oral health professional students' awareness, knowledge and attitudes toward environmental sustainability in dentistry.

Methodology

Study Setting

This study was conducted at the School of Clinical Dentistry, University of Sheffield. Ethical approval was granted by the Research Ethics Committee at the School of Clinical Dentistry, University of Sheffield (application number 061008). All proposed learning and teaching events were conducted within the formally delivered curriculum for the Bachelor of Dental Surgery (BDS) and Diploma in Dental Hygiene and Therapy (DH&DT) programmes. To evaluate the impact of the learning and teaching interventions, pre- and post-intervention assessments of students' awareness, attitudes and knowledge of ESD were measured using an online survey software, Qualtrics (https://www.qualtrics.com).

Eligibility Criteria

All students enrolled on the BDS programme and 1st year of the DH&DT programme were invited to participate in the study. Inclusion criteria for interested participants were: (i) be enrolled on the undergraduate dentistry (BDS) or diploma in dental hygiene and dental therapy (DH&DT) programme at the University of Sheffield and (ii) be able to attend or access all planned teaching sessions for Environmental Sustainability within their year of study.

Interventions

Four learning and teaching methods were termed 'interventions' in the context of the present research. These interventions were delivered to BDS and DH&DT students as part of the formal curriculum from September to November 2024. All interventions were developed using an evidence-based and research-centred approach, and all strategies and content have been published in peer-reviewed journals [323,326,327]. The interventions were:

- **Intervention 1 - Massive Open Online Course (MOOC) - Sustainability in Dentistry**: An online course developed by the Sustainability in Dentistry task team

of the FDI World Dental Federation [331]. This is an open-access resource, and the learning time is approximately three hours.

- **Intervention 2 - Standalone lecture for 'Environmental Sustainability in Dentistry'**: A one-hour in-person lecture that aims to describe the environmental impacts of oral healthcare and outline key strategies to mitigate these.
- **Intervention 3 – Teaching events with embedded ES content statements:** Embedding ES in existing learning and teaching events across all disciplines through the inclusion of 'content statements' as a single or group of slides [327].
- **Intervention 4 - Clinical case-based discussion centred around ES:** Case-based discussion of clinical scenarios that incorporate elements of ES alongside high-quality patient care. A two-hour session that included multiple cases in the field of restorative dentistry, endodontics, prosthodontics, periodontology and cariology.

Each year of study was exposed to a different mix of interventions to accommodate inclusion within the existing curriculum structure. This approach is beneficial because it represents a real-world example of embedding a topic in an existing curriculum. Additionally, conducting an analysis of the change in outcome measures according to year of study will provide insight into the individual and combined effects of the interventions (e.g. by comparing year groups that received single vs multiple intervention components).

Identification and Definition of Constructs

A survey was identified as a suitable tool to measure the impact of the interventions. Five constructs were identified as important outcomes to assess the effects of the interventions: awareness of ESD, attitudes towards ESD, knowledge of ESD, the extent to which implementing ESD is easy and general pro-environmental attitudes. How these constructs have been defined in the present research is outlined below:

- *Awareness of ESD*: defined as being conscious and cognisant of the impact of dentistry and oral healthcare on the environment and strategies to mitigate these impacts.

- *Attitudes towards ESD*: this work measures both cognitive and affective attitudes. Cognitive attitudes are defined as the evaluation implied by cognitions about ESD (e.g. the extent to which people believe that ESD is important and worthwhile). Affective attitudes are defined as the evaluation implied by feelings about ESD (e.g. the extent to which people believe that ESD is positive).

- *Knowledge ESD*: defined as a familiarity and understanding of ESD.

- *The extent to which implementing ESD is easy*: defined as the perception whether performing more environmentally sustainable oral healthcare is easy.

- *General Pro-Environmental Attitudes* - defined as an individual's overarching values, beliefs, and predispositions to care for and support the natural environment [302,332,333].

Delivery of Interventions

Figure 3 presents an overview of the curriculum initiative with respect to timing and year of study. Participants were required to complete the survey twice, once before the teaching interventions occurred, to acquire baseline data for the stated measures. The same survey was repeated after the interventions to analyse the effect of the interventions that aimed to increase awareness, knowledge, and attitudes toward ESD. The time lapse between the pre-and post-intervention surveys was planned for at least 6 weeks.

	1st BDS	2nd BDS & 1st DH&DT	3rd BDS	4th BDS	5th BDS
Pre-Intervention Survey	September 2024	September 2024	September 2024	September 2024	August 2024
Intervention 1: FDI 'Sustainability in Dentistry' MOOC	October 2024		September 2024		
Intervention 2: Standalone 'ES in Dentistry' lecture		October 2024			
Intervention 3: Embed ES content into existing events	1 event - October 2024	10 events Sepember - November 2024	3 events September - November 2024	7 events September - November 2024	
Intervention 4: Clinical case-based discussion including ES				October 2024	October 2024
Post-Intervention Survey	October 2024	November 2024	November 2024	November 2024	October 2024

Figure 3 - An overview of the planned interventions by year group.

Instrument Development

Two investigators (PhD candidate and co-author HMB) developed the first draft of the questionnaire through an iterative process over several meetings. The questionnaire was developed after an extensive literature search to identify any previous measures of awareness, knowledge, or attitudes towards ESD. A total of seventeen published articles were included in the review. Most sources did not report clear and transparent methodologies or failed to provide questionnaire items and, therefore, were identified as 'low quality'. Three articles provided relevant questionnaire items developed through a robust methodological approach [258,328,334]. These items were modified to fit the research question (dental and OHP education) and used in the first draft of the survey. Other items for awareness and knowledge of ESD were developed *de novo* due to an absence of previous measures. The survey used previously published and widely adopted measures of general pro-environmental attitudes [333,335], which allowed comparison against new measures to support their validity.

The first draft of the survey was presented, discussed, and amended in the presence of all researchers (PhD candidate, co-authors HMB, NM, JF). The final draft, before piloting, included 42 items across the following sections: demographics (7 items), awareness of ESD (4 items), attitudes towards ESD (17 items), general pro-environmental attitudes (8 items), and knowledge of ESD (6 items). Full descriptions of the final measures used in the study can be found in the section below (i.e. 'Final Survey Development').

A survey was created on Qualtrics, and the agreed items were uploaded. All questions were made mandatory. Item randomisation was used for the sections on awareness of ESD, attitudes towards ESD and general pro-environmental attitudes to reduce order effects and increase response validity.

Pre-testing and Piloting

A subgroup of BDS and DH&DT students from two dental schools in the UK tested the survey for face and content validity and to check for possible ceiling effects (i.e. when a large percentage of participants in a study score the highest possible score, meaning that detecting change because of an intervention is problematic). The institutions were external to the University of Sheffield to avoid exposing the survey to the target population. Ten additional items were added to the questionnaire to gather data regarding clarity of language, ease of use, accessibility, and survey length. A complete analysis of the pilot response data is provided in Appendix B.

Forty-four responses were received for the pilot questionnaire, although only 14 (32%) participants completed it fully. All dropouts occurred after the presentation of the participant information sheet and completion of the informed consent questions. Some minor amendments were made to the final survey to reduce the chances of drop-out, including adding a progress bar and providing an accurate estimation of the mean time to complete. The participant information sheet was converted to a link for participants to access. All these amendments were made to reduce the chances of participants feeling

overwhelmed by the amount of information provided and to improve response rates in the final survey.

All participants who fully completed the pilot survey were included in the analysis (n=14). Most respondents were female (64.3%) and were in their 4th year of study (50%), and the mean age of respondents was 24.9 years (*SD*=5.43). The pilot group appeared well aligned with the target population for the definitive survey regarding the programme of study and male/female ratios. However, the pilot subgroup may have had more academic and clinical experience than what may be observed in the final survey due to the participants' average age and year of study. As such, the researchers hypothesised that the pilot subgroup may perform better in the knowledge-based questions due to their prior experience.

A range of scores were observed for the 'awareness of ESD' and 'attitudes towards ESD' questions, demonstrating the effectiveness of the five-point response scales (Likert scales and radio dials). The mean scores for 'attitudes towards ESD' were higher than the 'awareness of ESD' and 'general pro-environmental attitudes' measures, meaning the risk for a ceiling effect was greater for this measure. However, no amendments were made to the survey due to the range of scores received and the observations made regarding subgroup demographics.

The pilot included six multiple-choice questions for 'knowledge of ESD'. A difficulty index and grade were calculated for each question by considering the percentage of the sample that selected the correct answer. This work was an adaptation of the work by Al Muhaissen *et al*. [336] to provide a grading system for knowledge-based questions that is relevant to this research area:

- Very difficult questions – difficulty rating less than 0.2 (<20% of the sample selected the correct answer)
- Challenging questions – difficulty rating between 0.2-0.49 (between 20% and 49% of the sample selected the correct answer)

- Acceptable questions – difficulty rating between 0.5 – 0.79 (between 50% and 79% of the sample selected the correct answer)
- Easy questions – difficulty rating between 0.8-1 (between 80% and 100% of the sample selected the correct answer)

Questions that are graded 'easy' are not desirable in this research as they suggest that most participants can select the correct answer without receiving the teaching intervention. One question received a difficulty grade of 'easy'; however, this question was not removed due to the subgroup's perceived greater academic and clinical experience. Three questions received an 'acceptable' difficulty grade, while the final two were rated as 'challenging' and 'very difficult'. To improve the knowledge-based questions for the final survey and to increase difficulty, an additional answer option was added to create five-option single-best answer questions. This method of assessment is widely accepted in health professional education [337].

Most of the subgroup (78.6%) agreed that the questions were easy to understand, although three participants (21.4%) encountered some difficulties. The free-text comments from these participants stated that item randomisation made completing the survey more complex, and some items were too long. Minor amendments were made to the final survey to shorten some statements. However, item randomisation was retained as it makes the research more robust by ensuring participants do not select the same option for all items without due consideration. Additionally, over 85% of respondents agreed that terms and phrasing of the items were clear, however, two respondents reported some difficulties in interpreting items that were phrased as a double negative (e.g. *"I do not care if the dental treatment(s) I provide harms the environment"* followed by the 'strongly disagree' answer option). To address these concerns, the final survey was amended to ensure the 'strongly agree' answer option appeared first to improve readability of the items. One knowledge-based multiple-choice question (namely *"Effective oral hygiene regimes…"*) was removed from the final survey due to a comment

expressing confusion about the answer options, which was acknowledged by the researchers.

Almost all respondents (93%) felt the questionnaire length was about right, with one reporting it was 'too long'. From the respondents' perspective, the mean time to complete the survey was 9.1 minutes (*SD*=2.99). The length of the survey aligned with the recommendations set out by Revilla *et al.* [338] , and as such, no further amendments were made.

Final Survey Development

After review of the pilot data analysis, a 41-item survey was finalised by the research team. The sections within the survey, the number of items and the response options/scales are presented in Table 8. The final version of the survey with information regarding the items included from previous research is available in Appendix C. No personally identifiable data was collected in the survey; participants were asked to generate a personal anonymous identifier code to allow matching of responses from both surveys in the follow-up data analysis.

Table 8 - Survey sections and number of items.

Survey Section	Number of Items	Response Options/ Scales	Example Item(s)
Demographics	7	A range of multiple choice and free-text options	Age, gender, year of study, experience of dentistry and ESD
Awareness of ESD	4	Five-point Likert scales	*"I am aware of the environmental impact of dentistry and oral healthcare"*
Attitudes towards ESD	17	Five-point Likert scales (8 items)	*"It is important to me that any dental treatment that I provide does not harm the environment"*

		Bipolar adjectives on a five-point radio dial (9 items)	*"To me, providing environmentally sustainable dentistry is:* *Good O O O O O Bad"*
General Pro-Environmental Attitudes	8	Five-point Likert scales	*"Compared to other things in my life, environmental problems are not that important to me"*
Knowledge of ESD	5	Five-answer option single best answer questions	*"The single best strategy to make dentistry more environmentally sustainable is:* *A. Recycle more single-use plastics* *B. Perform minimally invasive procedures* *C. Focus on the prevention of oral diseases* *D. Use eco-friendly materials* E. *Stop using dental amalgam"*

Notes. ESD = Environmental Sustainability in Dentistry.

Recruitment

Participants were invited to participate in the study in face-to-face lectures and by email. The principal investigator (PhD candidate) and co-author (NM) delivered in-person lectures at the start of the academic year (August/September 2024) to provide some information regarding the project, invite all students to participate and share a QR code to access and complete the pre-intervention survey. One year group (5th BDS) did not have any scheduled lectures and were therefore invited to participate by email. All invited participants received a participant information sheet that described the research, the advantages and disadvantages of participating and important details pertaining withdrawal and data management. Regardless of their decision to participate in the study,

all students were invited to attend the learning and teaching events as these were embedded in the formal curriculum. All potential participants were given the opportunity to ask questions either in person or via email. The approximate total sample pool is 375 students across all cohorts of the five-year BDS and first year of the DH&DT programmes. This study aimed to recruit at least 50% of the sample pool.

Data Analysis

The data was analysed using the IBM SPSS Statistics programme (version 29). Descriptive statistics were used to analyse the completion rates, demographic data and the general findings for all constructs. A correlation matrix was computed to explore the relationship between all five measured constructs. Correlations, t-tests and Multivariate Analyses of Variance (MANOVA) were used to explore whether the baseline measures differed according to sample demographics. To enable within-subject analysis, individual responses to both surveys were matched manually using the anonymous participant code. To analyse change in the measures pre- and post-intervention, a repeated measures MANOVA was conducted. To deduct the impact of individual teaching interventions, the MANOVA was modified to include year of study as a between-subjects factor.

Results

Pre-Intervention Data

A total of 351 survey responses were received, representing a response rate of 90%. Completion rates were favourable, with 333 respondents completing the survey in full, and only 18 (5%) incomplete submissions were received. Table 9 presents the completion rates and number of responses.

Table 9 - Number of survey responses and completion rates.

Completion Rates	Number of Responses
<20%	0
0-40%	11
41-60%	0
61-80%	7
81-99%	0
100%	333
Total	351

A total of 11 submissions were excluded from the analysis as completion ceased after the consent form and demographic section. The seven remaining incomplete submissions were included in the analysis where data was available, resulting in a total of 340 respondents.

Demographic Data

For gender identity, 218 (64.1%) identified as female, 114 (33.5%) identified as male, and 8 (2.4%) respondents selected the 'prefer not to say' or 'other' options. The gender split within the current sample appears to align with the figures reported locally and in Europe for undergraduate dental programmes [311]. Ages ranged from 18 to 44, with the mean age of respondents being 21.6 years (*SD* = 3.18). Most students (95.5%) were enrolled on the BDS degree, with 22 (4.5%) students enrolled on the DH&DT programme. Table 10 presents a breakdown of participants according to each year group of the BDS and DH&DT programmes. There were a similar number of responses for most year groups on the BDS programme, with 5th BDS responses (14.7%) slightly lower than other year groups (18.5 – 20.6%). The DH&DT programme has a smaller student cohort, and 22 responses were received from 23 registered students.

Table 10 - Responses received by year of study.

Year of Study	Number of Responses	Percentage of Whole Sample
1st BDS	70	20.6
2nd BDS	63	18.5
3rd BDS	65	19.1
4th BDS	70	20.6
5th BDS	50	14.7
1st DH&DT	22	6.5
Total	340	100.0

Notes. BDS = Bachelor of Dental Surgery, DH&DT= Dental Hygiene and Therapy Programme

Prior Experiences in Dentistry and Environmental Sustainability

Less than a quarter of the sample (*N* = 77; 22.6%) reported previously working in a dental practice. An exploration of the sample's prior experience of activities related to ESD was varied, with almost half (48%) of respondents not reporting any previous activities concerning ESD. However, of those that did report some prior experience of activities related to ESD, 91 (26.8%) respondents reported having attended a formal teaching session associated with ESD, 31 (11.2%) had attended a talk or a webinar related to ESD, 43 (12.6%) read a book or a published paper on ESD, and 103 (30.3%) of respondents had encountered the topic in the media. From the free-text responses that detailed other activities completed by participants concerning ESD (n=10), five respondents stated participation in a dental school ESD working group or research project, four responses related to watching or completing a webinar or an e-learning module, and one respondent reviewed this topic as part of a school-based project. A further 10 participants (2.9%) reported completing the FDI World Dental Federation 'Sustainability in Dentistry' MOOC.

Awareness and Attitudes Towards Environmental Sustainability in Dentistry Questions

Table 11 provides an overview of the baseline data exploring participants' awareness and attitudes towards ESD using descriptive statistics. The survey measured four constructs in this section: (i) awareness of ESD, (ii) attitudes towards ESD, (iii) the extent to which implementing ESD is easy, and (iv) general pro-environmental attitudes. All measures were rated on a five-point response scale, with higher scores reflecting greater awareness and more positive attitudes towards ESD and general pro-environmental attitudes. The attitudes towards ESD construct were measured in two ways: five-point Likert response scales and bipolar adjectives describing ESD using 5-point radio dials.

Table 11 - Descriptive statistics for the awareness and attitudes towards environmental sustainability in dentistry items.

Measure	*N*	Minimum	Maximum	*M*	*SD*	α
Awareness of ESD	338	1.00	5.00	2.99	0.76	0.83
Attitudes towards ESD (Likert scale)	338	2.63	5.00	4.23	0.51	0.84
Attitudes towards ESD (bipolar adjectives)	337	2.63	5.00	4.43	0.50	0.78
Extent to which implementing ESD is easy	337	1.00	5.00	2.47	0.88	
General pro-environmental attitudes	339	1.88	5.00	3.69	0.52	0.77

Notes. N = number; M = mean SD = Standard deviation; α = Cronbach's alpha; ESD = Environmental Sustainability in Dentistry.

Descriptive statistics indicated a wide range in participants' awareness of ESD, the extent to which implementing ESD is easy, and general pro-environmental attitudes (e.g., scores ranged from 1 to 5). The range for the two attitudinal measures towards ESD suggests that, overall, participants have positive attitudes towards ESD (all scores >2.50). The mean score for the extent to which implementing ESD is easy (*M*=2.47), awareness of ESD (*M*=2.99) and general environmental attitudes (*M*=3.69) were slightly lower than both the attitudes towards ESD measures (Likert scale *M*=4.23, bipolar adjectives *M*=4.43). These findings were expected and demonstrate that, overall, participants had more positive attitudes towards ESDs than awareness, general pro-environmental attitudes, and consideration of whether implementing ESD is easy. Ceiling effects occur when scores on a measure cluster near the maximum possible score in the first survey, making it difficult to detect change in participants when evaluating the effect of the intervention in a follow-up survey. Inspection of the baseline data suggests that the risk for ceiling effects is more likely for the measures that assess attitudes towards ESD, and, therefore, the study's potential to demonstrate change for these constructs may be lower.

Cronbach's alpha was calculated for awareness of ESD ($\alpha = 0.83$), both measures for attitudes towards ESD (Likert scale $\alpha = 0.84$, bipolar adjectives $\alpha = 0.88$) and general pro-environmental attitudes ($\alpha = 0.77$) demonstrating good to excellent internal reliability. Cronbach's alpha could not be calculated for the constructs 'extent to which implementing ESD is easy' as it is a single-item measure.

Knowledge of Environmental Sustainability in Dentistry Questions

Table 12 presents the results for the five single-best-answer questions that assessed participants' baseline knowledge of ESD. For each question, the percentage of students who selected the correct answer, the difficulty index, and the difficulty grade are provided. Questions 1 and 5 were rated as challenging, and question 2 was rated as very difficult. These findings are favourable as they suggest that it is difficult for respondents to select the correct answer without experiencing the teaching interventions. Questions 3 and 4 were rated as 'acceptable', suggesting it was easier for participants to choose the correct

answer, even though they had not experienced the teaching interventions. Positively, none of the questions were rated as 'easy'.

Table 12 - Descriptive statistics for knowledge of environmental sustainability in dentistry items.

Number	Question	Correct Answer Selected (%)	Difficulty Index	Difficulty Grade
1	*The single best strategy to make dentistry more environmentally sustainable is…*	36.9	0.37	Challenging
2	*Which option is the most significant contributor to the environmental impacts of dentistry and oral healthcare?*	8.1	0.08	Very Difficult
3	*Which of the following most accurately reflects the use of single-use plastics (SUPs) in dentistry?*	73.0	0.73	Acceptable
4	*What is the primary concern associated with the use of amalgam fillings?*	71.2	0.71	Acceptable
5	*What is the primary environmental benefit of using digital radiography in dentistry?*	32.4	0.32	Challenging

Performance on the knowledge of ESD questions varied among the 333 participants who completed this section, with 4.5% of respondents selecting no correct answers. Just over a

fifth of the sample (21%) selected one correct answer out of five, 36.3% scored two out of five, 26.1% scored three out of five, 10.6% scored four out of five, and only 1.5% of participants scored five out of five.

Relationship Between Baseline Constructs

Table 13 presents the bivariate correlations between the baseline variables in this study. General pro-environmental attitudes were positively associated with both measures for attitudes towards ESD (r=0.68 and r=0.47, p's <.01, for Likert scale and bipolar adjectives, respectively), suggesting that having more positive attitudes towards the environment is associated with more positive attitudes for ESD, specifically. The two measures for attitudes towards ESD (Likert scales and bipolar adjectives) were also positively associated (r=0.53, p<.01), suggesting a moderate-to-strong correlation between the attitudinal measures. However, this correlation was insufficient to consider combining the measures in the subsequent analyses.

There was a weak positive association between general pro-environmental attitudes and awareness of ESD (r=0.17, p<.01) and specific attitudes to ESD and awareness of ESD (Likert scale, r=0.18, p<.01), suggesting participants with more positive attitudes towards the environment, and ESD specifically, also have greater awareness of ESD. More positive general pro-environmental attitudes were also positively associated with greater knowledge of ESD (r=0.13, p<.05).

Table 13 - Correlations between measures.

Measures	2.	3.	4.	5.	6.
1. Awareness of ESD	0.18**	0.10	0.05	0.17**	0.09
2. Attitudes towards ESD (Likert scale)		0.53**	0.01	0.68**	0.09
3. Attitudes towards ESD (bipolar adjectives)			-0.04	0.47**	0.08

4. Extent to which implementing ESD is easy				-0.02	-0.07
5. General pro-environmental attitudes					0.13*
6. Knowledge of ESD					1.00

*Notes. ESD = Environmental Sustainability in Dentistry. * = correlation is significant at the 0.05 level, ** = correlation is significant at the 0.01 level.*

Influence of Sample Demographics on Baseline Measures

The next stage of the analysis was to explore whether there were any differences in sample demographics according to the measures collected at baseline. Such analyses will highlight any differences between groups of participants at baseline and identify possible control variables for the subsequent analyses testing the effects of the intervention.

Correlation analyses demonstrated statistically significant mild positive correlations between age and awareness of ESD (r=0.30, p <.01), knowledge of ESD (r=0.15, p <.01), general pro-environmental attitudes (r=0.15, p <.01) and attitudes to ESD (Likert scale, r=0.11, p <.05). In general, older participants had greater awareness and knowledge of ESD and had more positive general pro-environmental attitudes and specific attitudes to ESD.

Independent t-tests demonstrated that participants who identified as female (M= 3.74, SD= 0.49) had more favourable general pro-environmental attitudes than participants who identified as male (M= 3.56, SD= 0.55; t(329)=-3.07, p=.002, d_{cohen}= 0.35). Attitudes towards ESD (measured through bipolar adjectives) were also more positive in participants who identified as female (M= 34.49, SD= 0.51) than males (M= 4.33, SD= 0.47; t(328)=-2.70, p=.007, d_{cohen}= 0.35). This aligns with previous research findings that demonstrate that, in general, females are more environmentally conscious [339,340]. Females (M= 2.30, SD= 1.10) also performed better on the knowledge of ESD questions than males (M= 2.04, SD= 1.00; t(324)=-2.10, p=.040, d_{cohen}= 0.26). No significant differences were noted between participants identified as male and female with respect to attitudes towards ESD

(measured by Likert scales), awareness of ESD, and the extent to which implementing ESD is easy.

An independent t-test was performed to compare responses between the two programmes of study. This demonstrated that DH&DT students (*M*= 3.82, *SD*= 0.62) reported greater awareness of ESD compared to BDS students (*M*= 2.94, *SD*= 0.74; *t*(336)=-5.38, *p*<.001, d_{cohen}= 1.29). No other statistically significant differences were noted between BDS and DH&DT students for any other constructs.

A MANOVA test was conducted to compare responses for all baseline measures across year groups of the BDS programme. Across all of the measures, there were significant differences observed between the years of study and the combined dependent variables *F*(24,1058)=1.72, *p*=.017, partial n^2=.03. Inspection of univariate tests revealed that there were no significant differences between years of study for the measures: attitudes towards ESD, general pro-environmental attitudes and the extent to which implementing ESD is easy (*p*>.05). However, a significant difference between year of study was observed for awareness of ESD (*F*(4,308)=3.17, *p*=.014, partial n^2=.04) and knowledge of ESD (*F*(4,308)=5.86, *p*<.001, partial n^2=.07). Post-hoc tests demonstrated that there were significant differences in awareness of ESD between participants in 1st BDS and 3rd BDS. Third-year BDS students (*M*=3.14, *SD*=0.75) demonstrated greater awareness of ESD than first-year BDS students (*M*=2.77, *SD*=0.74, *p*=.032). Additionally, significant differences in knowledge were identified between 1st BDS (*M*=1.80, *SD*=1.08) and 4th BDS (*M*=2.49, *SD*=1.00, *p*=.001) and 5th BDS (*M*=2.56, *SD*=1.05, *p*=.001). Table 14 provides an overview of the means and standard deviations for each construct according to BDS year group.

Table 14 – Baseline data for the constructs according to year of study.

Measures	1st BDS Mean (SD)	2nd BDS Mean (SD)	3rd BDS Mean (SD)	4th BDS Mean (SD)	5th BDS Mean (SD)
Awareness of ESD	2.77 (0.74)	2.85 (0.76)	3.14 (0.75)	2.86 (0.68)	3.14 (0.67)
Attitudes towards ESD (Likert scale)	4.24 (0.5)	4.17 (0.52)	4.24 (0.52)	4.26 (0.52)	4.18 (0.48)
Attitudes towards ESD (bipolar adjectives)	4.42 (0.51)	4.42 (0.54)	4.41 (0.46)	4.46 (0.50)	4.40 (0.50)
Extent to which implementing ESD is easy	2.49 (0.91)	2.55 (0.78)	2.54 (0.79)	2.39 (0.89)	2.31 (0.98)
General pro-environmental attitudes	3.64 (0.52)	3.64 (0.48)	3.70 (0.55)	3.71 (0.51)	3.73 (0.54)
Knowledge of ESD	1.80 (1.08)	2.03 (1.03)	2.27 (1.01)	2.49 (1.00)	2.56 (1.05)

Influence of Previous Work Experience

An independent t-test demonstrated that participants who had previously worked in a dental clinic (M= 3.42, SD= 0.70) had significantly greater awareness of ESD compared to participants who had never worked in a dental practice (M= 2.87, SD= 0.73; $t(336)$=5.92, p=<0.01). No other statistically significant relationships were identified between previous work experience and the measured constructs.

Post-Intervention Data

Completion Data and Participant Matching

A total of 363 responses were received for the follow-up survey. Twenty-five incomplete responses were removed from the data set as they only included responses to the consent form and demographic sections. The final dataset included 338 submissions, of which 321 were fully completed. The pre-and post-survey responses were matched to an individual using the personal anonymous identifier code submitted in the demographics section. Participant matching was completed manually using the statistics software SPSS. In cases where the anonymous codes were similar but not identical, demographics were used to verify that responses were from the same individual. In these cases, some assumptions were made:

i. A match was confirmed if slight variations in the anonymous code were noted and the demographics were the same, although the stated age was one year older in the post-intervention survey.
ii. A match was confirmed if slight variations were noted in the anonymous code if other demographics were the same, but the gender changed to 'prefer not to say' in one of the surveys.
iii. A match was confirmed if the ‘number of siblings’ and ‘number for the day you were born’ parts of the unique code and the demographic information were identical.

A total of 270 matched participants were confirmed in the final dataset. The remaining responses could not be matched due to differences in the anonymous code submitted. The overall demographics of the final dataset were similar to the baseline survey results, with a mean age of 21.6 years (*SD*=3.25), and 66.3% of participants identified as female. Concerning the year of study, a similar split was noticed in the final dataset, with 1st BDS forming 23% of the sample, 2nd BDS 20.7%, 3rd BDS 19.6%, 4th BDS 17.4%, 5th BDS 13% and 1st DH&DT representing 6.3%.

Comparing Measures Acquired at Baseline and Post-Intervention

Analysis of the pre-intervention data revealed that there was a significant difference in gender according to several of the outcome variables. As such, the subsequent analyses were conducted twice, once with and once without controlling for gender. Given that the overall findings remained unchanged, the findings from these analyses are reported below without controlling for gender. Age was also found to be associated with some of the outcome measures in the pre-intervention survey, however, as age is likely to be associated with year of study (one of the between-subject variables in our planned analyses), age was not controlled for in the analyses.

A repeated measures MANOVA was conducted for the six outcome measures (awareness of ESD, attitudes towards ESD – Likert scales, attitudes towards ESD – bipolar adjectives, extent to which implementing ESD is easy, general pro-environmental attitudes and knowledge of ESD) to identify if there was a change in the outcome measures for the whole cohort from baseline to post-intervention. Multivariate analysis revealed a significant change in the combined dependent variables across the two timepoints $F(6,234)=58.77$, $p<.001$, partial $n^2=.60$.

Follow-up univariate analyses indicated that there were significant differences from pre- to post-intervention for awareness of ESD ($F(1,239)=285.54$, $p<.001$, partial $n^2=.54$), both measures for attitudes towards ESD (Likert scale $F(1,239)=6.54$, $p=.011$, partial $n^2=.03$; bipolar adjectives $F(1,239)=10.73$, $p=.001$, partial $n^2=.04$), general pro-environmental attitudes ($F(1,239)=19.40$, $p<.001$, partial $n^2=.08$) and knowledge of ESD ($F(1,239)=93.10$, $p<.001$, partial $n^2=.28$). There was no difference in the extent to which participants reported that implementing ESD is easy before or after the intervention ($p=.552$). The means and standard deviations for each outcome measure across the two timepoints are presented in Table 15.

Post-hoc tests demonstrated that awareness of ESD improved from baseline ($M=2.94$) to post-intervention ($M=3.82$, $p<.001$). Attitudes towards ESD demonstrated a smaller but

statistically significant positive shift from baseline (Likert scales *M*=4.24, bipolar adjectives *M* = 4.44) to post-intervention (Likert scales *M*=4.32 *p*=.011, bipolar adjectives *M*=4.54 *p*=.001). General pro-environmental attitudes improved from baseline (*M*=3.70) to post-intervention (*M*=3.80, *p*<.001) and knowledge of ESD also demonstrated a positive change from baseline (*M*=2.28) to post-intervention (*M*=3.07, *p*<.001).

Table 15 - Means, standard errors and p values for the outcome measures across the two timepoints.

Measures	Time	Mean	SE	*p* value
Awareness of ESD	1 (Pre)	2.94	0.05	<.001*
	2 (Post)	3.82	0.04	
Attitudes towards ESD (Likert scale)	1 (Pre)	4.24	0.03	.011*
	2 (Post)	4.32	0.03	
Attitudes towards ESD (bipolar adjectives)	1 (Pre)	4.44	0.03	.001*
	2 (Post)	4.54	0.03	
Extent to which implementing ESD is easy	1 (Pre)	2.46	0.06	.552
	2 (Post)	2.50	0.06	
General pro-environmental attitudes	1 (Pre)	3.70	0.03	<.001*
	2 (Post)	3.80	0.03	
Knowledge of ESD	1 (Pre)	2.28	0.07	<0.01*
	2 (Post)	3.07	0.08	

*Notes. ESD = Environmental Sustainability in Dentistry. SE = standard error. * = statistically significant as p<.05*

The Influence of the Independent Variables on the Extent of Change

As different year groups received a different combination of teaching interventions, analysing the influence of the year of study on the extent of change in the outcome measures could reveal the individual or combined effects of the teaching interventions. As such, a five-between (year of study: 1st BDS, 2nd BDS, 3rd BDS, 4th BDS, 5th BDS) by two-within (time point: pre vs post-intervention) mixed MANOVA was conducted on the six outcome measures. This analysis revealed a statistically significant interaction between the year of study and the two timepoints (pre- and post-intervention) across the six outcome measures $F(24,818)=2.59$, $p<.001$, partial $n^2=.06$).

Univariate analyses demonstrated statistically significant differences by year of study from baseline to post-intervention for the following outcome measures: awareness of ESD $F(4,239)=5.22$, $p<.001$, partial $n^2=.08$, general pro-environmental attitudes $F(4,239)=2.92$, $p=.022$, partial $n^2=.05$ and knowledge of ESD $F(4,239)=4.67$, $p=.001$, partial $n^2=.07$. The interaction between year of study across the two timepoints was not significant for attitudes towards ESD (both Likert scales and bipolar adjectives) and the extent to which implementing ESD is easy.

Table 16 presents the means and standard errors for each outcome measure across the year of study and the two timepoints. The *p*-values are also provided to demonstrate where there was significant change in the outcome measures from baseline to post-intervention by year of study. Statistically significant positive changes in awareness of ESD were observed for all years of study (*p's*<.001). For attitudes towards ESD, statistically significant changes were only noted for 1st BDS from baseline (measured through bipolar adjectives $M=4.45$) to post-intervention ($M=4.64$, $p=.002$) and for 2nd BDS from baseline (measured through Likert scales $M=4.23$) to post-intervention ($M=4.38$, $p=.015$). Statistically significant positive changes in general pro-environmental attitudes were observed for 1st BDS ($p<.001$), 2nd BDS ($p=.001$) and 3rd BDS ($p=.031$) from baseline to post-intervention. Knowledge of ESD significantly improved from baseline to post-intervention for all years of study (*p's*<.05).

Table 16 - Means, standard errors and p values for the outcome measures across year of study and two timepoints.

Measures	Year of Study	Time	Mean	SE	*p* value
Awareness of ESD	1st BDS	1 (Pre)	2.74	0.094	<.001*
		2 (Post)	4.02	0.076	
	2nd BDS	1 (Pre)	2.86	0.10	<.001*
		2 (Post)	3.82	0.08	
	3rd BDS	1 (Pre)	3.09	0.10	<.001*
		2 (Post)	3.83	0.08	
	4th BDS	1 (Pre)	2.83	0.11	<.001*
		2 (Post)	3.64	0.09	
	5th BDS	1 (Pre)	3.16	0.13	<.001*
		2 (Post)	3.77	0.11	
Attitudes towards ESD (Likert scale)	1st BDS	1 (Pre)	4.28	0.06	.337
		2 (Post)	4.33	0.07	
	2nd BDS	1 (Pre)	4.23	0.07	.015*
		2 (Post)	4.38	0.07	
	3rd BDS	1 (Pre)	4.21	0.07	.441
		2 (Post)	4.26	0.07	
	4th BDS	1 (Pre)	4.31	0.07	.870
		2 (Post)	4.32	0.08	
	5th BDS	1 (Pre)	4.19	0.09	.163
		2 (Post)	4.30	0.09	
	1st BDS	1 (Pre)	4.45	0.06	.002*

Attitudes towards ESD (bipolar adjectives)					
		2 (Post)	4.64	0.06	
	2nd BDS	1 (Pre)	4.42	0.07	.125
		2 (Post)	4.52	0.06	
	3rd BDS	1 (Pre)	4.39	0.07	.412
		2 (Post)	4.44	0.06	
	4th BDS	1 (Pre)	4.47	0.07	.362
		2 (Post)	4.53	0.07	
	5th BDS	1 (Pre)	4.47	0.09	.210
		2 (Post)	4.57	0.08	
Extent to which implementing ESD is easy	1st BDS	1 (Pre)	2.43	0.11	.515
		2 (Post)	2.51	0.11	
	2nd BDS	1 (Pre)	2.52	0.12	.782
		2 (Post)	2.49	0.12	
	3rd BDS	1 (Pre)	2.59	0.12	.324
		2 (Post)	2.42	0.12	
	4th BDS	1 (Pre)	2.40	0.13	.134
		2 (Post)	2.61	0.13	
	5th BDS	1 (Pre)	2.39	0.16	.715
		2 (Post)	2.45	0.16	
General pro-environmental attitudes	1st BDS	1 (Pre)	3.69	0.06	<.001*
		2 (Post)	3.90	0.07	
	2nd BDS	1 (Pre)	3.69	0.07	.001*
		2 (Post)	3.85	0.07	

	3rd BDS	1 (Pre)	3.62	0.07	0.031*
		2 (Post)	3.72	0.07	
	4th BDS	1 (Pre)	3.72	0.07	.644
		2 (Post)	3.74	0.08	
	5th BDS	1 (Pre)	3.79	0.09	.901
		2 (Post)	3.80	0.09	
Knowledge of ESD	1st BDS	1 (Pre)	1.97	0.14	.006*
		2 (Post)	2.41	0.16	
	2nd BDS	1 (Pre)	2.04	0.14	<.001*
		2 (Post)	3.44	0.17	
	3rd BDS	1 (Pre)	2.21	0.15	<.001*
		2 (Post)	2.96	0.17	
	4th BDS	1 (Pre)	2.57	0.16	<.001*
		2 (Post)	3.22	0.18	
	5th BDS	1 (Pre)	2.61	0.19	.002*
		2 (Post)	3.32	0.22	

*Notes. ESD = Environmental Sustainability in Dentistry. SE = standard error. * = statistically significant as p<.05*

To provide a visual summary of the findings reported above, Figures 4 to 8 plot the mean scores for each of the significant univariate interactions. Figure 4 plots the mean scores for awareness of ESD for each year of study across the two time intervals. In support of the means provided in Table 16, an increase in awareness for all year groups can be noted with a particularly steeper increase for 1st BDS that started from the lowest baseline mean score and progressed to the highest post-intervention mean score compared to other years of study. The gradient of increase in awareness of ESD is similar across year groups 2nd BDS to 4th BDS is similar, with 5th BDS demonstrating a flatter line suggesting the change in this

outcome measure was lower for this year of study, although still significantly greater than baseline (as shown in Table 16).

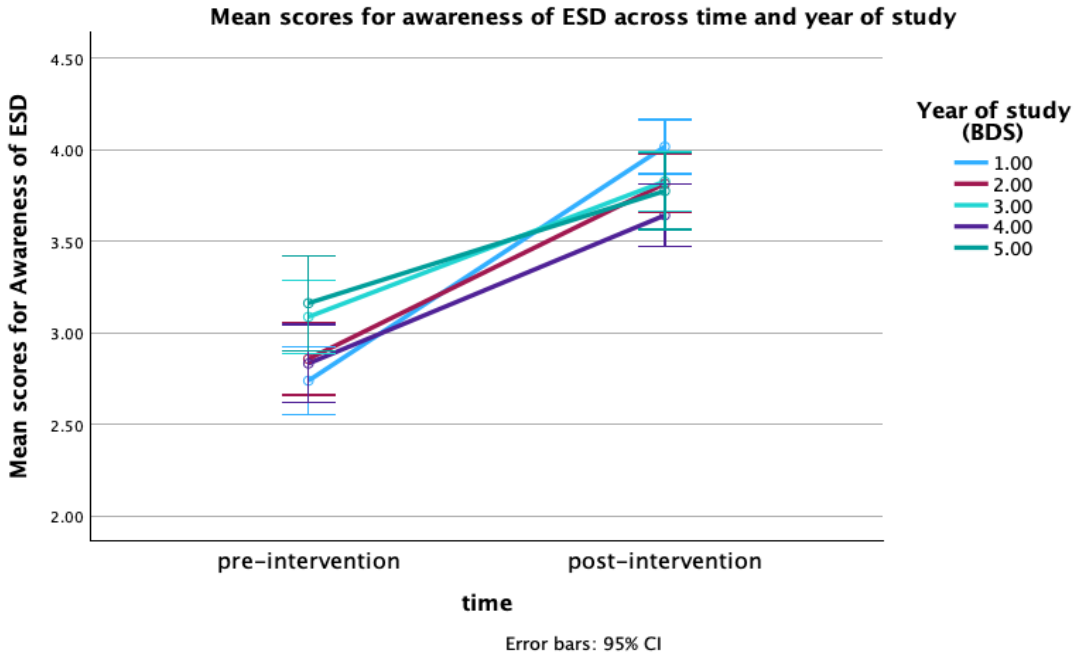

Figure 4 - A line graph presenting the mean scores for awareness of ESD across time and year of study. Note: the y-axis scale has been shortened to improve the visibility of the changes in mean scores, the complete scale is from 1 to 5.

Figures 5 and 6 present line graphs for the attitudes towards ESD outcome measures measured through Likert scales and bipolar adjectives, respectively. Whilst the MANOVA demonstrated no significant changes in these outcome measures across time and the year of study combined, there were some significant changes in these measures from baseline to post-intervention for certain year groups. For attitudes towards ESD that were measured through Likert scales, the line graph illustrates a steeper increase for 2nd BDS, which was statistically significant (Figure 5). Additionally, 1st BDS students reported a greater increase in attitudes towards ESD measured through bipolar adjectives compared to other years of study, which was also statistically significant (Figure 6).

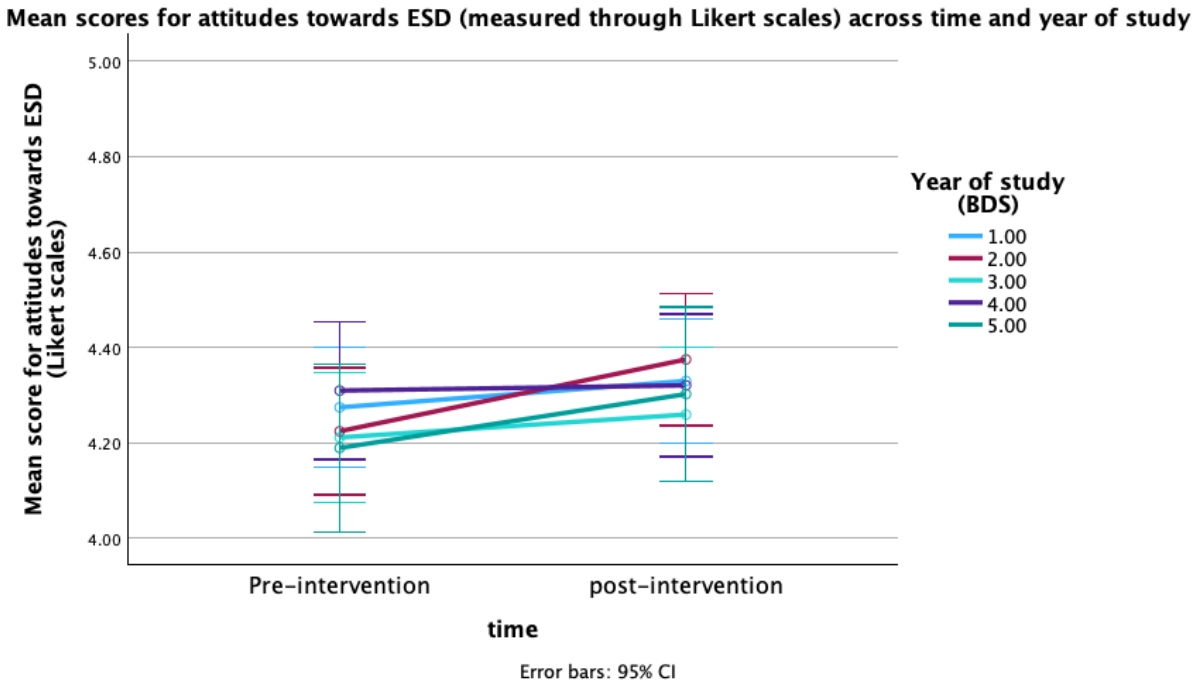

Figure 5 - A line graph presenting the mean scores for attitudes towards ESD (measured through Likert scales) across time and year of study. Note: the y-axis scale has been shortened to improve the visibility of the changes in mean scores, the complete scale is from 1 to 5.

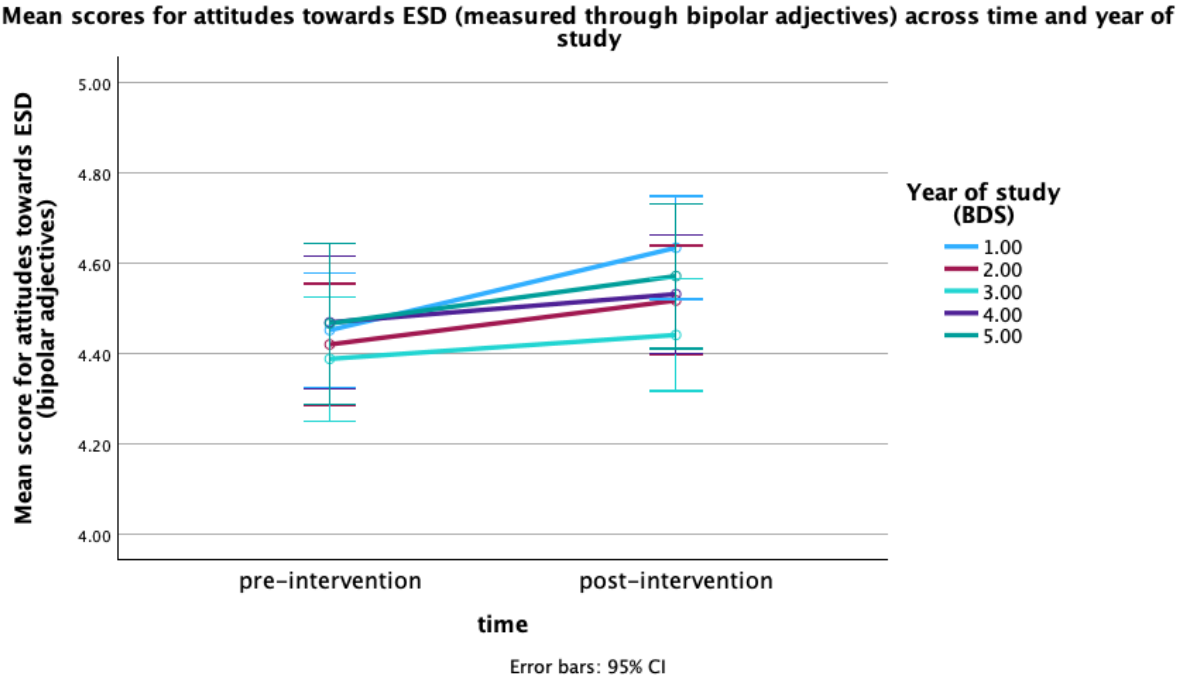

Figure 6 - A line graph presenting the mean scores for attitudes towards ESD (measured through bipolar adjectives across time and year of study. Note: the y-axis scale has been shortened to improve the visibility of the changes in mean scores, the complete scale is from 1 to 5.

Figure 7 presents the mean scores for general pro-environmental attitudes across all years of study and the two timepoints on a line graph. Univariate analyses from the MANOVA demonstrated a significant change in this outcome measures across all year groups combined from baseline to post-intervention. The graph demonstrates that the 1st BDS had the steepest increase in this outcome measure, with the 2nd and 3rd BDS also demonstrating statistically significant positive changes in this measure. No significant changes in this outcome measure were observed for the 4th and 5th BDS.

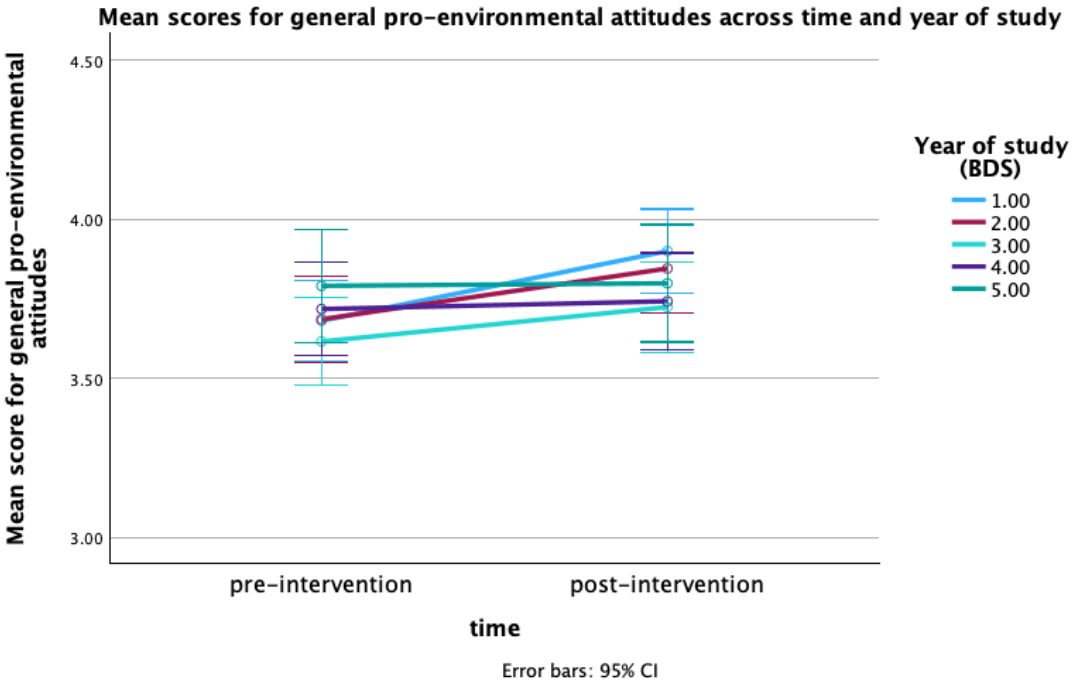

Figure 7 - A line graph presenting the mean scores for general pro-environmental attitudes across time and year of study. Note: the y-axis scale has been shortened to improve the visibility of the changes in mean scores, the complete scale is from 1 to 5.

The changes in knowledge of ESD across years of study from baseline to post-intervention are presented in Figure 8 as a line graph. All year groups demonstrate positive changes in knowledge of ESD, with 2nd BDS showing the steepest increase in knowledge of ESD. 3rd BDS, 4th BDS, and 5th BDS demonstrate similar gradients of knowledge increase from baseline to post-intervention, with 1st BDS presenting the smallest overall change in this outcome measure.

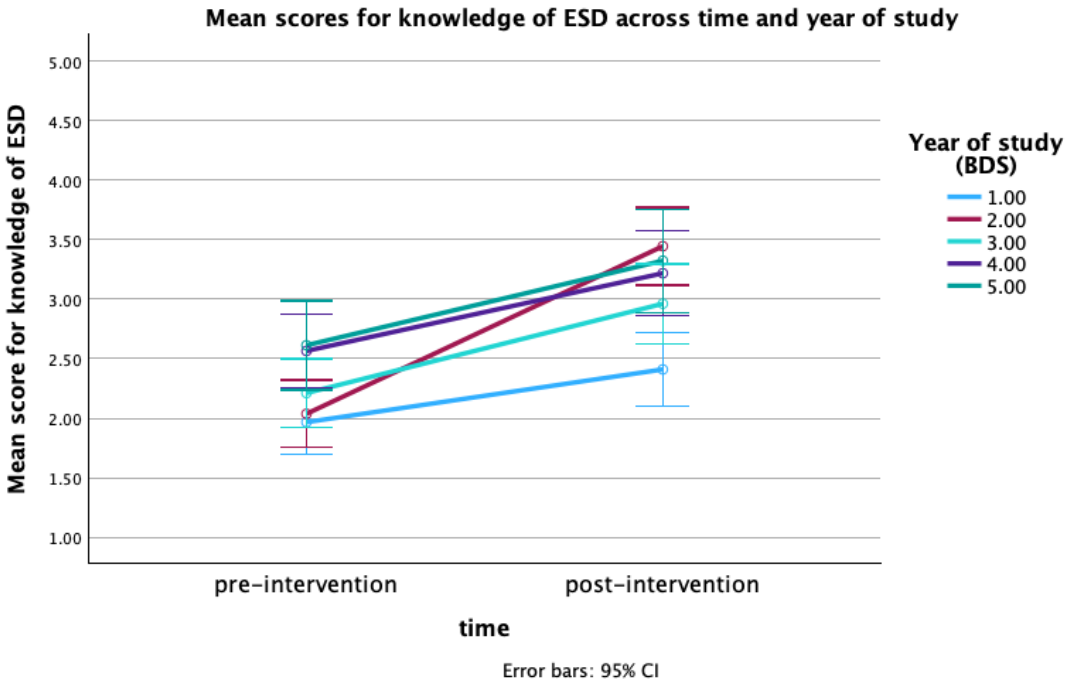

Figure 8 - A line graph presenting the mean scores for knowledge of ESD across time and year of study. Note: the y-axis scale has been shortened to improve the visibility of the changes in mean scores, the complete scale is from 0 to 5.

Discussion

This study has demonstrated that embedding ES longitudinally into the dental curriculum across all years of study is achievable and effective by employing a pragmatic and education research-based approach. The teaching interventions for ES had a significant positive effect on students' awareness of ESD, attitudes towards ESD, general pro-environmental attitudes and knowledge of ESD. No significant differences were noted regarding students' perception of the extent to which implementing ESD is easy, perhaps reflecting an acknowledgement of the current barriers to delivering environmentally sustainable oral healthcare [11,251,323,324]. The largest improvements from baseline to post-intervention were noted for awareness and knowledge of ESD regardless of the year of study. Before commencing this work, the researchers anticipated that it would be more complex to demonstrate a change in both specific attitudes (to ESD) and general pro-

environmental attitudes, as awareness and knowledge are recognised as contributors to attitudinal development [341,342]. Additionally, it is acknowledged in the literature that attitude change is complex and is dependent on the strength of the pre-existing values and beliefs [343]. Positive attitudes are a necessary prerequisite for behaviour change, however, the direct relationship between attitudes and behaviours is complex and not fully understood [299–301,344]. It is positive that statistically significant changes have been noted for the specific and general attitudinal measures. However, the overall changes are lower than the awareness and knowledge constructs, likely due to the higher baseline score for attitudes and a resultant ceiling effect and an appreciation that attitude change may require longer-term exposure to the topic.

The strategic plan for this curriculum initiative was developed from numerous educational research projects [323,324,326,327]. A comprehensive approach to situational analysis and needs assessment was performed to establish a need for change [13,309,312,323,324]. The current context concerning ES in undergraduate dental and OHP education was explored through surveys that demonstrated limited published evidence of dental schools longitudinally integrating ES in the curriculum [311,312,323,324]. Learning outcomes for the interventions were selected from the Association for Dental Education in Europe (ADEE) consensus document and the recent update to the General Dental Council (GDC) national framework in the UK [15,326]. From this, appropriate teaching and assessment methods were chosen to ensure constructive alignment [119]. The selected approaches were informed by the themes that emerged from exploratory focus groups with local educators and students [327]. These established the need to teach ES across all disciplines, the importance of baseline knowledge transmission with practical reinforcement of the topic and provided valuable proposals to incorporate ES into *existing* teaching and assessment events. Educators across all curriculum subjects were provided evidence-based and subject-specific content to augment their teaching events [327].

The four interventions were integrated across all year groups according to the opportunities presented in the existing curriculum. This demonstrates an example of an

approach to embedding ES within a local curriculum structure where there is limited flexibility or space to add numerous new events. In this study, the FDI 'Sustainability in Dentistry' MOOC was delivered to 1st and 3rd BDS students to provide core baseline knowledge of ES in dentistry and oral healthcare. It was necessary to select two-year groups for this intervention initially, as students had not experienced any ESD teaching previously in the curriculum. In the future, the MOOC will be delivered to one year group only to avoid repetition. A standalone lecture was delivered in a face-to-face format for 2nd BDS and 1st DH&DT, which provided information regarding climate change, the contribution of dentistry to the climate crisis and proposed strategies to deliver more environmentally sustainable oral healthcare. The timing of this lecture coincided with the pre-clinical skills practical course, which also included sustainability teaching through flipped classroom learning and in-person practical teaching. The evidence-based content statements were embedded into 21 *pre*-existing events as a single or group of slides across four years of study. These events included lectures and flipped learning from 10 different curriculum subjects, including dental public health, cariology, periodontology, paediatric dentistry, oral pathology and professionalism and ethics. The case-based discussion provided an opportunity for 4th and 5th BDS students to review patient care planning and develop an understanding of how structured and smart care delivery can mitigate the environmental impact of the care provided. The environmental impact of various treatment modalities was also reviewed.

The results from the MANOVA for each outcome measure over time, which included year of study as a between-subjects factor, provide insight into the impact of individual or a mix of interventions. All years of study demonstrated a significant improvement in awareness of ESD, suggesting all four interventions were effective for this outcome measure. However, 1st BDS, who received the MOOC and one lecture on professionalism and ethics that included content statements on ES, demonstrated the greatest increase in awareness. Potentially, this occurred due to a lack of previous dental experience and the steep learning curve for this new student cohort who had to gain an understanding of dentistry

and ES through the MOOC. Additionally, there was more scope for improvement due to the lower baseline score reported for this outcome measure.

For attitudes towards ESD, a smaller change was noted, and the pairwise comparison for each year group revealed that only 1st BDS and 2nd BDS presented significant differences in this outcome measure from baseline to post-intervention. As 2nd BDS received more teaching interventions compared to other year groups (dedicated ES lecture and ten events with content statements) and were exposed to practical learning of ES in a clinical simulation setting, it can be hypothesised that cumulative learning and practical reinforcement is needed to promote attitudinal changes. Interestingly, the 4th and 5th BDS were the only year groups that did not demonstrate a significant change in general pro-environmental attitudes. These year groups did not receive any baseline knowledge teaching for ES and only experienced practical application of the topic in a case-based discussion. This finding demonstrates the importance of baseline knowledge transmission in the early years of programmes, as discussed in previous research by Dixon *et al.* [327]. With respect to knowledge of ESD, positive changes were noted for all years of study, demonstrating the effectiveness of all teaching interventions in improving knowledge. The greatest increase in knowledge of ESD was observed in 2nd BDS, again demonstrating the impact of more teaching hours and the need for practical reinforcement [327]. The lowest increase in knowledge of ESD was noted for 1st BDS, perhaps reflecting this cohort's lack of academic and clinical experience but also potentially the limitations of using an online resource exclusively for education in this area.

The results of this study are very promising and provide evidence that strategically planned, and contextually correct learning and teaching can improve awareness and knowledge and change attitudes. This is of particular importance in the current educational context where socio-cultural topics are being embedded in the curriculum with anticipation that attitudinal learning will occur. Additionally, as this curriculum initiative interweaves ES content across all years of the undergraduate dental programme, it is anticipated that the cumulative learning from all interventions will result in a greater

change in awareness, attitudes and knowledge of ESD at the end of the five-year cycle than what has been observed in this study that assessed change within a single academic year.

The review of the literature suggests that this is the first published example of planning, implementing and evaluating the longitudinal integration of ES in a formally delivered health professional curriculum. Previous examples of teaching ES have been limited to smaller-scale interventions typically applied opportunistically at one point in the curriculum [306,307,345,346]. These early interventions appeared to be led by educators with a particular interest in ES and served as an excellent starting point to raise awareness. However, these studies have demonstrated that single events may improve knowledge of ESD but are unlikely to result in meaningful changes to awareness and attitudes towards ESD [306,346].

The main limitation of this work relates to the difficulties encountered when matching participants' pre- and post-intervention responses, due to variations in the personal anonymous identifier code reported. This resulted in a loss of participants in the final comparative analyses. For future work, consideration should be made to emphasise the importance of accurate submission of the code during participant recruitment and also modifying the code and the associated instructions.

Opportunities for Future Research

This study has demonstrated the positive impact of ES-specific teaching interventions on awareness, specific attitudes, general attitudes and knowledge of ESD within a single academic year. As this approach has embedded ES across all years of the undergraduate dental programme, a long-term review of the impact of these interventions across the length of the curriculum would be of interest, with a particular focus on the magnitude of change for specific attitudes towards ESD and general pro-environmental attitudes. Additionally, exploring the impact of these positive changes in attitudes on behaviour would be of interest. Finally, this research-centred approach to curriculum development

could be applied to other constructs such as social accountability, resilience and interprofessional education.

Conclusion

This study provides a real-world example of how ES can be longitudinally embedded in the dental curriculum with minimal disruption to the existing educational philosophies and goals. Four teaching interventions were used: the FDI 'Sustainability in Dentistry' MOOC, a dedicated ESD lecture, integration of ES content statements in existing teaching events, and a clinical case-based discussion including ES concepts. The effectiveness of this approach has been confirmed through an evaluation of the change in awareness of ESD, attitudes towards ESD, general pro-environmental attitudes and knowledge of ESD before and after the curriculum initiative. Significant positive changes were noted for all outcome measures except the extent to which implementing ESD is easy. The most significant changes were noted for awareness of ESD and knowledge of ESD across all years of study. General pro-environmental attitudes and specific attitudes towards ESD demonstrated a lower gradient of change, perhaps reflecting the need to review the impact of the cumulative learning events on these outcome measures in the longer term across the whole curriculum. All four teaching interventions appeared effective, although increased exposure to ES teaching and practical learning seemed to be significant positive indicators of change. The need for baseline ES teaching in the early years of programmes was also observed.

Chapter IX – A Toolkit for Curriculum Development in Dental Education

Introduction

The dental and oral health professional (OHP) curriculum must be open, transparent, and continuously developed to reflect the changing profession and world. The overarching goal of dental and OHP education remains the same; to produce high-quality practitioners, although the necessary knowledge, skills, and behaviours to achieve this outcome are frequently amended [4,15]. Recent changes in this context include the addition of professionalism and ethics in the curriculum, the use of hybrid teaching modalities and the phase-down of dental amalgam and its impact on the teaching of adhesive dentistry. Curriculum development in dental and OHP programmes is typically driven by:

- New developments in the discipline [6,8,147,158]
- Educational rationale and innovation [67,160,347,348]
- Changes in society and stakeholder priorities [13,62,162–164,330]

Occasionally, a large-scale curriculum change is needed after an extensive review of all curricular elements. In this respect, curriculum change often involves a complete rebuild of the curriculum and a change in overall philosophy. However, this type of curriculum change is extremely resource-intensive, and regularly repeating this process is unsustainable in most contexts. A more flexible and manageable curriculum development process is necessary to update the *existing* curriculum frequently to ensure it is fit for purpose. Curriculum development in most contexts can be considered a cyclical, planned, and progressive process of improving existing educational practices and curricula.

While curriculum development has been undertaken in dental and OHP education for some time, there is limited evidence to describe *how* this is achieved. Numerous published models support curriculum development in health professional education [5,8,18,19]. Most of these refer to large-scale curriculum change and compare different curriculum

philosophies. Kern's model [5] refers to the development of existing curricula and is frequently cited in the health professional education literature. However, this model may now be considered outdated, and the terminology used does not reflect the reality of current educational practice.

This chapter proposes an evidence-based curriculum development model based on contemporary dental and OHP education practice. The research completed previously in this thesis, which focused on embedding environmental sustainability (ES) in the dental and OHP curriculum, will be used as a case study to validate the proposed model.

A New Model for Curriculum Development in Dental Education

A new model for curriculum development in dental and OHP education has been developed to incorporate new terminology and practices (Figure 9). This model also better represents stakeholder collaboration and the importance of regular regulatory, institutional, school and programme-level quality assurance. The seven components are:

1. Curriculum mapping
2. Situational analysis and needs assessment
3. Definition of learning outcomes
4. Selection of teaching and assessment methods
5. Content development and organisation
6. Implementation
7. Evaluation and feedback

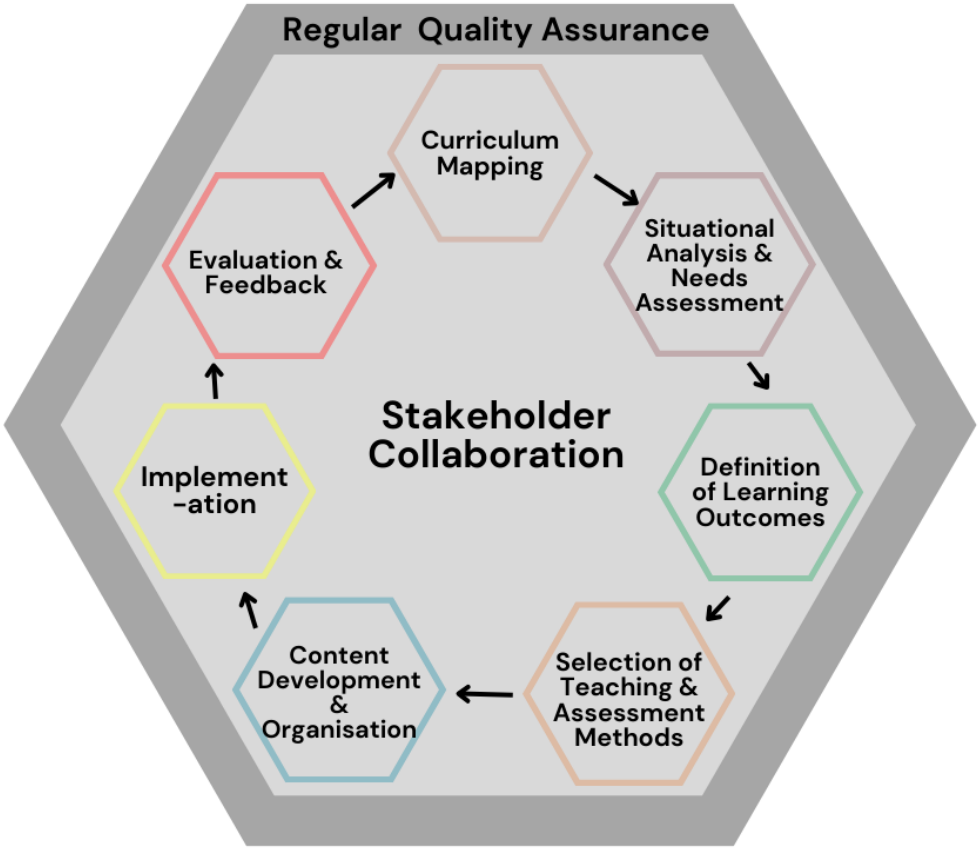

Figure 9 - A contemporary approach to curriculum development in dental and oral health professional education.

Curriculum development is not an isolated activity with a defined end date but a cyclical and continuous process. Evaluation and feedback must inform future practice [349]. Stakeholder input and collaboration are critical across all aspects of this process. Additionally, regular quality assurance processes allow for a critical inquiry into the curriculum through multiple lenses. Both stakeholder collaboration and quality assurance are fundamental components of the curriculum development process and, therefore, contribute to all individual stages described below.

Curriculum Mapping

Curriculum mapping is the start and end point of the curriculum development cycle. This process provides educators with rapid access to the curriculum at any time. It allows direct visualisation of the location of learning outcomes in the curriculum and the methods used

to teach and assess these [52]. Additionally, curriculum mapping provides complete transparency and awareness of the current situation that is visible to all stakeholders [350].

Curriculum mapping allows for the interrogation of learning outcomes to identify opportunities for curriculum development. It enables rapid cross-referencing to avoid duplicating teaching/assessment events and determine whether new changes will make other learning outcomes redundant. This overview also allows educators to identify the institutional thresholds for change and create a realistic and achievable plan of action based on the existing situation.

Situational Analysis and Needs Assessment

A case for change must be established from a comprehensive analysis of the existing situation and the needs of stakeholders. Following quality assurance processes, current practice should be compared to an ideal example, with any differences representing the needs assessment [5]. Consultation with stakeholders will provide a different context for the planned changes and raise potential barriers to change [351,352]. Various methodologies may be used to establish a needs assessment, including quantitative (survey questionnaires, clinical performance data) and qualitative (focus groups, interviews) data collection, literature searches and policies from regulators [9].

In addition to establishing a case for change, it is necessary to perform a comprehensive analysis of the situation in which change will occur. This should include:

- Resource analysis: including staffing numbers, skills and experience, space, clinical/simulation units, technology, and funding.
- Performance analysis: consider student and staff performance in the area of interest and comparison with other institutions.
- Content analysis: current curriculum content in the area of interest and potential opportunities for reinforcement.
- Training suitability analysis: is the graduating workforce appropriate for existing and future population needs?

- Cost-benefit/utility analysis: selecting cost and time-effective interventions to maximise benefit.

The results of these processes provide significant insight into the drivers for change and the key challenges to implementing the curriculum development project. Identifying these two competing 'forces' from the start of the process is critical to producing a viable pathway for success. Lewin's force field analysis theory is used widely in social science for change management and states that existing 'driving' and 'restraining' forces are currently balanced to reflect the current situation [178]. An imbalance is needed to deliver change by accelerating the 'driving' forces and limiting the impact of the 'restraining' forces. Producing a vision for the curriculum development process and incorporating a strategy to manage these contextual factors are essential starting points.

Definition of Learning Outcomes

Defining the overarching educational goals for the intervention provides clarity for all stakeholders and produces a vision that should be compatible with the existing situation and resource availability [351,352]. Learning outcomes are recognised as the core component of outcome-based curricula that are widely adopted in health professional education [2,4,15,275]. Learning outcomes have been defined as *"a series of individual and objective outcomes, with shared ownership between students and staff, designed to facilitate the learning and assessment process"* [310]. They should state the expected learning that the student must achieve and use meaningful verbs appropriate to the learning mode according to Bloom's domains [106].

If the planned curriculum development requires new learning outcomes, they should be clear and concise to provide structure for students and educators. Published curriculum documents may be used, or the dental school can develop learning outcomes internally. Stakeholder collaboration is essential, and using consensus-based methodologies such as the Delphi process is recommended to develop new learning outcomes [353,8,65]. However, to reduce the risk of increasing the number of learning outcomes exponentially, existing

learning outcomes can be modified and adapted in many contexts to include the new curriculum elements. Additionally, curriculum mapping must ensure that redundant learning outcomes are removed.

Selection of Teaching and Assessment Methods

After the intended learning outcomes for the new curricular elements have been developed, the most suitable teaching and assessment methods should be selected [5]. The methods employed must be suitable for the defined cognitive level of the learning outcome [106,120]. Constructive alignment between teaching and assessment methods and defined learning outcomes is a core approach used in contemporary dental education [119]. This ensures complete alignment in all critical elements of the formal curriculum; the learning outcomes must inform the teaching and assessment methods, and the assessment methods must reflect the learning outcomes, and the teaching received. Considering the overloaded nature of dental curricula, in many cases, it may be preferable to amend existing teaching and assessment methods to incorporate the desired change. However, innovative teaching and assessment methods may need to be developed for more novel subjects.

Content Development and Organisation

Teaching content should be written to align with the learning outcomes and teaching and assessment methods selected in step four of the curriculum development cycle. Educators and students must be empowered to take ownership of the change to maximise efficiency and impact [352]. Staff and faculty education events must be in place to provide the relevant knowledge to support the change and allow educators to tailor their content to the changing context. Student buy-in is equally important, and co-creating learning content is a valuable way to collaborate and contribute to the goals of the proposed intervention [354]. Alongside the organisation of content, effective and efficient administration around learning outcomes should be managed. This includes the delivery, mapping, storing, accessibility and aligned assessments for each learning outcome. Effective cross-

referencing of new learning outcomes with the existing curriculum is essential to avoid duplication.

Implementation

Implementing the proposed curriculum development initiative requires explicit communication of all previous planning work outcomes to gain approval and support from school and university committees. Relevant bodies must also approve the administrative aspects of the changes. The new curriculum intervention must then be clearly communicated to staff, students, and other stakeholders, with open streams for discussion. Piloting the intervention may help gain insight into its feasibility and uncover any barriers [5].

Evaluation and Feedback

Evaluating the outcome of the pedagogic intervention is a critical element of the curriculum development cycle. An exploratory approach through educational research can reveal the success of the new curriculum intervention. Accessible and anonymous evaluation streams must be available to provide constructive feedback on the process adopted by the curriculum developers. It must be ascertained whether the intervention has been useful, time- and cost-effective, and feedback should inform future developments [181]. Input from all stakeholders of dental and OHP education should be sought where possible. Student feedback processes play a significant role across HEIs as the receiver of education. Equally, constructive feedback from staff, as the deliverers of the curriculum, should lead to refining the change. Additionally, external quality assurance processes, including school visits, regulator assessments and external examiners, can provide a different perspective on developments in the curriculum. Evaluation processes should feed back into the needs assessment, emphasising the ongoing cyclical nature of curriculum development.

Case Study: Embedding Environmental Sustainability into the Dental Curriculum

ES is an emerging societal challenge that mandates all sectors to reconsider their practices. Dentistry has been highlighted as an area of concern due to the significant environmental impacts of oral healthcare provision, principally resulting from patient travel, staff commuting, procurement of dental products, energy and water consumption, and waste production [10,11,202]. Multiple stakeholders, including national regulators, have recognised the need to embed ES in undergraduate dental and OHP curricula [15].

The research described in the previous chapters of this thesis provides evidence of an effective curriculum development process by embedding ES in the undergraduate OHP curriculum. The following sections will review the curriculum development cycle in the context of ES and provide examples of practice.

Curriculum Mapping

While not a specific research output, a curriculum mapping process was performed to identify existing educational practices and opportunities to incorporate new concepts such as ES. Reviewing the existing curriculum in diagrammatic form allowed visualisation of the placement and relationship of different curricular elements and helped to shape the strategy that was developed in future stages. Holding all teaching and assessment events in a single database facilitated rapid review and enabled direct mapping of ES to existing events.

Situational Analysis and Needs Assessment

Educational research informed an extensive situational analysis and needs assessment. To better understand the state of dental and OHP education in Europe, a scoping review and pan-continental surveys were used (reported in Chapter IV) [308,311,312]. This research provided critical insight into existing curriculum structures and practices across a continent that all follow the same professional qualifications directive [36,37]. This research and the

development of the vision for OHP education (reported in Chapter IV) provided a stakeholder-agreed gold standard that the local curriculum should aspire to reach [308,309,311,312]. Specifically for ES, current educational practice, drivers and barriers were explored nationally and across Europe through mixed methods approaches (reported in Chapter V) [323,324]. The results of this research provided an important understanding of the current situation, facilitated local planning and identified key barriers to change.

Locally, the student voice, as a key stakeholder of OHP education, was included through a survey of student opinion regarding the importance and relevance of ES in the undergraduate dental curriculum (reported in Chapter VI) [328]. This supported previous work in other contexts that demonstrated significant support for including ES in the curriculum from multiple stakeholders, including educators, students, educational organisations, and national regulators [13–15,251,270,273,274,326]. From this point, the need to embed ES in the local curriculum was clear.

Definition of Learning Outcomes

The ADEE 'Sustainability in Dentistry' special-interest group conducted a pan-European consultation to write specific learning outcomes for ES (reported in Chapter VI) [326]. The group developed seven new learning outcomes and modified seven items from the original Graduating European Dentist (GED) framework [4]. The General Dental Council (GDC) in the United Kingdom (UK) used this document and included two learning outcomes in the recent curriculum update, the Safe Practitioner framework [15]. Locally, these documents were used to inform the plan to embed ES in the curriculum. As the GDC is the national regulator of the UK, the two learning outcomes for ES had to be incorporated into the plan, and one additional learning outcome from the ADEE work was included. The learning outcomes selected were:

i. Describe the main principles relating to sustainable oral health care, both environmentally and in terms of patient compliance, and the factors that might affect implementing a sustainable approach.

ii. Evaluate and apply the evidence base in relation to the environmental impacts of common treatment methods and approaches to the delivery of oral healthcare.
iii. Develop effective patient-specific strategies for preventive oral health, reducing the need for recall, operative intervention, and material use.

Selection of Teaching and Assessment Methods

The learning outcomes developed informed the proposed teaching and assessment methods for ES. The ADEE 'Sustainability in Dentistry' special-interest group proposed teaching and assessment methods for each learning outcome to ensure constructive alignment of all elements (reported in Chapter VI) [326]. An additional stakeholder, the FDI World Dental Federation have also produced evidence-based learning content in the form of a Massive Open Online Course (MOOC) which aims to educate the profession at all levels [331]. To gather stakeholder opinions locally, focus groups were conducted with educators and students to identify opportunities to teach and assess each learning outcome within the local curriculum (reported in Chapter VI) [327]. This research methodology provided excellent insight into the possibility of *modifying* the existing teaching and assessment methods without the need to add multiple new events. Considering the results of all the outputs described, four teaching methods were planned across all years of the undergraduate OHP curriculum:

i. Massive Open Online Course (MOOC) FDI World Dental Federation- Sustainability in Dentistry: an online course with an approximate learning time of three hours [331]. Embedded into 1st year dentistry and 1st year dental hygiene and therapy programmes.
ii. Standalone lecture titled 'Environmental Sustainability in Dentistry': – a one-hour lecture providing baseline knowledge regarding ES and key mitigation strategies. Delivered to 2nd year dental and 1st year dental hygiene and therapy students.
iii. Embedding ES content into existing learning and teaching events across all disciplines**:** through inclusion 'content statements' as a single or group of slides [327]. Delivered to years 1-4 of the dentistry programme.

iv. Clinical case-based discussion including ES: clinical scenarios that incorporate elements of ES alongside high-quality patient care. A single two-hour session that included multiple cases in the field of restorative dentistry, endodontics, prosthodontics, periodontology and cariology. Delivered to 4th and 5th year dentistry students.

Existing methods of assessments were augmented to include ES components, including OSCEs, written examinations and online quizzes. As this curriculum development project progresses and students receive more teaching relating to ES across all years of study, ES will be incorporated to a greater extent into other assessments.

Content Development and Organisation

Given the methods selected and educators' reported unfamiliarity with the topic of ES, it became increasingly clear that evidence-based and subject-specific content needed to be developed in the field of environmental sustainability in dentistry (ESD) [251,273,274,323,324]. A research methodology grounded in exploring the evidence base and achieving stakeholder consensus resulted in the development of 44 content statements for ESD (reported in Chapter VII) [327]. The content statements were mapped to all curriculum subjects and validated through subject-expert consultation. This work enabled educators of all disciplines to identify and use evidence-based content on ES that was relevant to their area of expertise. Slide decks were developed for all disciplines and shared with educators. A collaborative approach between curriculum managers and educators was completed to identify existing teaching events that were relevant to ES, and the educators received the evidence-based content that could be added to their teaching in the form of one or multiple slides.

Implementation

The work completed in the previous steps informed a plan to embed ES in the local curriculum. The strategy was agreed upon locally through the relevant quality assurance processes. The curriculum development project commenced in September 2024, and the planned teaching events were delivered to all year groups (reported in Chapter VIII).

Effective organisation and clear communication of the planned changes were critical. Additionally, it was important to provide support and reassurance to educators and students during this change.

Evaluation and Feedback

Multiple methods of evaluation and feedback were used to review the process and outcome of embedding ES in the curriculum. To measure the impact of the teaching interventions on student awareness, attitudes and knowledge of ESD, baseline and post-intervention surveys were completed (reported in Chapter VIII). This demonstrated that embedding ES across all years of the undergraduate dental programme resulted in significant changes in OHP students' awareness of ESD, attitudes towards ESD, general pro-environmental attitudes and knowledge of ESD. Additionally, student satisfaction surveys were completed as part of routine internal quality assurance to review student perceptions of this curriculum development initiative. These findings provided critical insight into the intervention's success and helped improve this process for the next cycle.

Conclusions and Recommendations

A curriculum development cycle is critical to ensure dental and OHP education remains fit for purpose to meet the needs of a frequently evolving profession. This chapter proposes a new model of curriculum development that is better suited to current OHP educational practices. This approach utilises contemporary educational terminology and better reflects the importance of stakeholder collaboration and quality assurance processes.

The following recommendations have been developed:

- Utilise an easy-to-use and effective curriculum mapping software to give critical insight into existing curricula practices.
- Conduct extensive local and regional needs assessments to identify the drivers for curriculum development and establish a gold standard of practice.

- Review the constraints of the existing curriculum through a situational analysis to identify and predict challenges to the proposed development project.
- Carefully and objectively select learning outcomes for the planned change and ensure sustainability by modifying existing learning outcomes and removing redundant items.
- Constructively align selected learning outcomes with teaching and assessment methods and explore opportunities to augment existing events.
- Employ multiple methods of evaluation to review the impact of the intervention across all relevant stakeholders.
- Engage and collaborate with key stakeholders to plan, implement and evaluate proposed curriculum initiatives.

Chapter X – Summary and Conclusions

The research presented in this thesis has answered the overarching research question *'How does the undergraduate dental curriculum evolve to incorporate new concepts, such as environmental sustainability?'* by illustrating a systematic and structured approach to curriculum development through the lens of environmental sustainability (ES). The aim of this research was to implement and evaluate a curriculum development model to embed environmental sustainability in undergraduate dental education. This aim has been achieved through careful and structured completion of the objectives, utilising a range of rigorous research methodologies that were grounded in stakeholder consultation.

The current state of dental and OHP education in Europe was explored through a scoping review and surveys (reported in Chapter IV) [308,311,312]. The scoping review concluded that there was very little reporting of dental and OHP professional education across Europe and established the need for a data collection process across Europe. A 'living' survey in the form of a datahub was developed that allowed dental schools to control and update their own data. The datahub was shared with all ADEE members and a 50% response rate was achieved. The results were presented in two separate publications (also reported in Chapter IV) and provide key data regarding programme details, curriculum structure and educational practices from over 70 dental schools across 25 different European countries [311,312]. This was the first attempt to collect comprehensive data on programme structures and curriculum practices across Europe, which provided key insight to inform the next steps of the project.

Two studies were developed to gain an understanding into existing teaching practice for ES in dental education (reported in Chapter V). A mixed methods approach was adopted at a European level which included a survey and interactive workshop to identify common challenges to embedding ES in the curriculum and to propose key strategies to overcome these [323]. Additionally, a survey was disseminated to all UK and Irish dental schools to identify current teaching practice for ES [324]. These studies illustrated that most schools

reportedly do not currently teach ES and are facing numerous challenges, particularly in clinical contexts. Numerous barriers to embedding ES in the curriculum were identified including a lack of curriculum space, expertise to teach ES and resources for educators and students.

Specific learning outcomes for ES and aligned teaching and assessment methods were developed through a consensus-based approach (reported in Chapter VI) [326]. Two of these learning outcomes were adopted by the General Dental Council (GDC) and made the teaching of ES mandatory in dental schools within the United Kingdom from 2025 [15]. Focus groups were used to explore student and educator views on the relevance of ES and opportunities to embed ES within the local curriculum (also reported in Chapter VI) [327]. Multiple themes were uncovered including the need to practically reinforce ES teaching and teach ES across all disciplines. Importantly, it was identified that there are opportunities to augment or modify *existing* teaching and assessment events to include ES. This is beneficial as it avoids adding numerous new events for ES in an already overloaded curriculum.

As educators currently feel there is a lack of expertise to teach ES within their institution, it became clear that evidence-based content needed to be developed. An approach grounded in evidence and consultation with multiple stakeholders was used to develop content statements for ES (reported in Chapter VII) [327]. These serve as key messages for ES that can be embedded into existing teaching events, perhaps in the form of a single or multiple slides. The statements were mapped to all curriculum subjects in dental and OHP education. This allows educators to identify evidence-based and subject-specific content that they can embed within their teaching. This work should give educators confidence that the information they are providing is evidence-based, particularly in a subject area that is open to misinformation and disinformation.

All previous research findings informed a plan to longitudinally embed ES across all years of the dental curriculum. Four teaching interventions were delivered as part of the formal curriculum: (i) FDI 'Sustainability in Dentistry' MOOC, (ii) standalone lecture

‘Environmental Sustainability in Dentistry’, (iii) content statements embedded into lectures across all curriculum subjects, (iv) case-based discussion including ES concepts. A survey was used to assess students’ awareness of environmental sustainability in dentistry (ESD), attitudes towards ESD and knowledge of ESD at baseline and post-intervention to evaluate whether and to what extent the interventions had a positive impact on these outcome measures (reported in Chapter VIII). This research demonstrated significant and positive changes in awareness of ESD, attitudes towards ESD, general pro-environmental attitudes and knowledge of ESD from baseline to post-intervention demonstrating the effectiveness of the curriculum initiative. The findings of this study reinforced the need to embed ES across numerous curriculum subjects and provide baseline teaching on ES concepts with opportunities for practical learning.

A new model for curriculum development in dental and OHP education has been presented after being validated through the education research described previously in this thesis (reported in Chapter IX). The model incorporates more contemporaneous educational terminology and reflects the current favouring of the learning outcomes-based curriculum model. As evidenced by the research completed previously, stakeholder collaboration forms a key part of the model. Examples of practice for each stage of the model have been discussed through the lens of ES.

Limitations of the Research

Whilst the approaches selected were robust and inclusive of stakeholder views, the candidate acknowledges some limitations with the research undertaken. The research completed has considered and delivered change in the formal curriculum, however the interaction between the ethos and culture of the institution on both the informal and hidden curriculum should be considered as an important part of embedding topics such as ES. Numerous initiatives are ongoing to include and normalise ES in all departmental activities, although describing these is not within the scope of this project.

The limitations of each study is reported in Chapters IV – VIII. The project as a whole presents a structured approach to curriculum development through the lens of environmental sustainability. The evaluation of the success of this intervention considered the change in student awareness, attitudes and knowledge of ESD – a key outcome measure. However, with additional time and resources, further research should be performed to evaluate the curriculum development project from the perspective of academic staff, curriculum managers and administrative personnel to consider 'disruption' from another context.

Additionally, it should be acknowledged that this research and curriculum initiative is a starting point, and it is important to consider that this curriculum initiative should be reviewed again after a five-year cycle to evaluate the effect of the cumulative learning across the length of the curriculum on the outcome measures. Additionally, reviewing the process of embedding ES more extensively in existing assessment methods must be considered. Finally, the impact of this curriculum initiative on environmentally sustainable clinical behaviours should be investigated and the relationship between attitude and behaviour change in the context of ESD should be considered.

Conclusion

This project has demonstrated how the dental curriculum evolves to incorporate new concepts such as ES. An educational research approach has been employed to systematically plan, implement and evaluate the process of embedding ES in the undergraduate dental curriculum. A real-world example of a longitudinally integrated ES curriculum has been presented and significant changes in awareness, attitudes and knowledge of ESD were demonstrated from this approach. Additionally, the research results have demonstrated that it is feasible to embed new concepts within an existing curriculum with minimal disruption. Further investigations should be undertaken to explore the experiences of academic staff and curriculum managers throughout this curriculum initiative. A new model for curriculum development has been created that will

help educators and higher education institutions embed stakeholder collaboration and quality assurance within the ethos of this process.

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Appendices

Appendix A – Focus Group Script for 'Exploring Staff and Students Views on the Relevance and Opportunities for Environmental Sustainability in the Undergraduate Dental Curriculum'.

Introduction

1. Provide a brief overview of the curriculum development project and plans for the session.
2. Introduce the principal investigator and rapporteur. Confirm that the sessions will be audio recorded and that each participant will have a code to link comments while maintaining anonymity.
3. Introduce Wooclap, a software used to submit responses - discussion will be developed from the responses.

Demographic/Baseline Questions: collected via Wooclap using polls and free-text responses

1. Students: Please state your year and programme of study.

2. Staff: Please state the speciality/discipline in which you teach.

3. Have you previously worked on embedding Environmental Sustainability in the curriculum?

Embedding Environmental Sustainability in the Curriculum in Sheffield - Questions

Three learning outcomes have been selected to be taught and assessed across the length of the curriculum. These are:

- Explain the importance of practising sustainable oral health care
- Apply the scientific knowledge base in relation to the environmental impacts of common treatment methods, and common approaches to the delivery of care
- Develop effective patient-specific strategies for preventive oral health, reducing the need for recall, operative intervention, and material use

Please rank each learning outcome according to: (collected via Wooclap using polls)

1. Clarity of language: clear or not
2. Importance in the curriculum: essential (must teach), important (should teach), aspirational (could teach).

For “Explain the importance of practising sustainable oral health care” (collected via Wooclap using free-text answers)

1. How do you think this learning outcome would be best taught? Why…
2. How do you think this learning outcome would be best observed/assessed? Why…

For “Apply the scientific knowledge base in relation to the environmental impacts of common treatment methods, and common approaches to the delivery of care” (collected via Wooclap using free-text answers)

1. How do you think this learning outcome would be best taught? Why…
2. How do you think this learning outcome would be best observed/assessed? Why…

For “Develop effective patient-specific strategies for preventive oral health, reducing the need for recall, operative intervention, and material use” (collected via Wooclap using free-text answers)

1. How do you think this learning outcome would be best taught? Why…
2. How do you think this learning outcome would be best observed/assessed? Why…

Appendix B – Chapter VIII – Complete Analysis of the Pilot Questionnaire Data and Justification for Amendments to Final Survey

Completion Data

Table B1: An overview of the completion rates and number of responses.

Completion Rates	Number of Responses
<20%	22
20-40%	2
41-60%	6
61-80%	0
81-99%	0
100%	14
Total	**44**

This pilot study observed a high number of incompletions. Most incompletions (73%) occurred after less than 20% of the survey had been completed (i.e., after the consent form and demographic information were completed).

Considering the drop-out rate observed during the pilot study, some small changes were made to improve the completion rates of the final survey. First, an accurate estimation of the mean time to complete the survey has been added to the landing page of the survey; this was calculated from the pilot survey responses below. Second, a progress bar was added to the survey to inform participants about their progress. Third, the

researchers also felt that the length of the participant information sheet was overwhelming for participants and, therefore, may have reduced survey completion rates. As the recruitment process will include in-person and online recruitment via email, the participant information sheet will be shared in the recruitment messages. Therefore, the participant information sheet in the survey was converted to a hyperlink to avoid repetition. Finally, during recruitment, the researchers will emphasise the importance of completing the whole survey and repeat the estimated length of the survey.

Demographics

Of the 14 respondents who completed the survey in full, nine (64.3%) were female and five (35.7%) were male. This gender split likely represents the real-world male-to-female ratio of the target population. The mean age of respondents was 24.9 years (SD = 5.43). All respondents were enrolled in a Bachelor's Degree in Dental Surgery (BDS). Most participants reported being in their 4th year of study (50%) and the range was from year 3 to year 5. The stage of the respondents in this pilot data aligns with the senior students in my target population. However, the absence of early-year students (year 1 and 2) and students enrolled on dental hygiene and dental therapy programmes in the pilot study may mean that the pilot responses do not reflect those of the target population. It is likely that the average student who completed the pilot study has more academic and clinical experience than the average student who will complete the final survey. Therefore, it is hypothesised that the pilot respondents may perform better in the knowledge-based questions due to their prior experience.

The demographic data for prior experience of activities related to Environmental Sustainability in Dentistry was varied. Five respondents have attended a formal teaching session, a talk or a webinar or have encountered the topic in the media. Three respondents had read a published paper or book chapter, and one respondent had completed a dissertation on the topic. The respondents to this pilot may respond more positively to the awareness and attitudes to Environmental Sustainability in Dentistry questionnaire items and may perform better in the knowledge-based questions due to

these prior experiences. No participants completed the FDI World Dental Federation 'Sustainability in Dentistry' MOOC and 11 (78.6%) respondents had not worked in dental practice previously.

Action taken: as no problems were identified with the demographics section, no changes were made to the final survey. Some observations have been made regarding the demographics of the pilot population and their potential influence on the responses received.

Awareness and Attitudes towards Environmental Sustainability in Dentistry Questions

Table B2 provides an overview of the pilot data for awareness and attitudes towards the ESD items using descriptive statistics. There are four combined items: awareness of ESD, attitudes to ESD, bipolar adjectives describing ESD and general environmental attitudes. All items had a five-point response scale, with one the lowest rating and five the highest. Across all items, a range of scores were provided, which provides evidence of the effectiveness of the five-point scale. The mean score for awareness of ESD and general attitudes were lower than the attitudes and bipolar adjectives for ESD and centred around the 'neither agree nor disagree' option. The attitudes and bipolar adjectives mean responses aligned with the 'agree' option. The risk for a ceiling effect is greater for the attitudinal scores. However, the range of scores received and the potential favourable demographics to more positive attitudes to ESD scores led the researchers to proceed without modification.

Table B2 - Descriptive statistics for the awareness and attitudes towards Environmental Sustainability in Dentistry items.

Measure	N	Minimum	Maximum	M	SD
Awareness of ESD	14	1.25	4.25	3.16	0.94
Attitudes towards ESD (Likert scale)	14	2.75	5.00	4.14	0.74

Attitudes towards ESD (bipolar adjectives)	14	2.22	5.00	4.17	0.69
General pro-environmental attitudes	14	2.50	4.88	3.78	0.74

Knowledge of Environmental Sustainability in Dentistry Questions

Table B3 presents the results from the pilot for the six knowledge-based single best answer questions. The correct answer selected as a percentage, the difficulty index and difficulty grade are provided for each question. The difficulty index demonstrates the difficulty of the question, and a modification of the work by Al Muhaissen et al. (2019) has been made to create a grading system that is suitable for this study:

- Very difficult questions – difficulty rating less than 0.2
- Challenging questions – difficulty rating between 0.2-0.49
- Acceptable questions – difficulty rating between 0.5 – 0.79
- Easy questions – difficulty rating between 0.8-1

Table B3 - Descriptive statistics for knowledge of Environmental Sustainability in Dentistry items.

Number	Question	Correct Answer Selected (%)	Difficulty Index	Difficulty Grade
1	*The single best strategy to make dentistry more environmentally sustainable is*	21.4	0.21	Challenging

2	*Which option is the most significant contributor to the environmental impacts of dentistry and oral healthcare*	14.3	0.14	Very difficult
3	*Which of the following most accurately reflects the use of single-use plastics (SUPs) in dentistry*	57.1	0.57	Acceptable
4	*What is the primary concern associated with the use of amalgam fillings?*	92.9	0.92	Easy
5	*What is the primary environmental benefit of using digital radiography in dentistry?*	57.1	0.57	Acceptable
6	*Effective oral hygiene regimes*	64.3	0.64	Acceptable

As this study aims to demonstrate the impact of learning and teaching interventions, a question that is graded ‘easy’ would mean that it is easy to guess the correct answer without receiving the dedicated teaching content. An easy question would, therefore, limit the study's potential to demonstrate a significant change in knowledge regarding ESD. Questions one and two were rated as challenging and very difficult, respectively; this is viewed as a positive as it is difficult for respondents to select the correct answer without experiencing the teaching interventions. Questions three to six were rated as ‘acceptable’ or ‘easy’, suggesting it was easier for participants to select the correct answer, even though they had not experienced the teaching interventions. However, this cohort's prior academic and clinical experience may mean they were more likely to answer the question correctly. As the final survey will include students from earlier years (i.e., those with less

academic and clinical experience),the researchers felt these questions may still be good discriminators, and hence, all questions were retained. However, to align with educational literature and a transition to ‘single-best answer’ questions in health professional education, an additional answer option was added to all knowledge-based questions. This may also potentially make the questions more challenging in the final survey.

Pilot Evaluation Questions

The pilot evaluation questions aimed to gather opinions regarding the clarity and ease of understanding of the survey items and the overall length. Each respondent reported being able to respond to all the questions in the questionnaire.

Questionnaire ease-of-understanding and clarity

Over 78% of participants felt none of the questions were difficult to understand, whilst three participants (21.4%) reported some difficulties. The free-text comments were:

- “Perhaps it would be easier if all questions were standardised so that they are all negative or all positive, to avoid people chosing wrong answer by accident. I.e. some questions say "i don't care about the environment...." whilst other say "the environment is important to me..."
- “They were not difficult to understand, I just did not like how the rating scale of strongly agree and strongly disagree would change order. So I thought I had pressed one but it was the opposite of what I wanted. Keeping the options always in the same order would prevent erroneous answers.”
- “Too wordy a bit”

Action taken: The researchers reviewed the terminology used within the questions and made minor modifications to simplify or shorten some of the questions in the attitudes and awareness of ESD sections of the survey. Whilst the researchers acknowledge that the item randomisation may make the survey more time-consuming to complete, it is more robust to ensure respondents do not select the same answer for each question without

due consideration of the item. Therefore, the randomisation has not been removed from the survey.

Over 85% of respondents reported that no terms used in the questionnaire were confusing, whilst two respondents did. The free-text comments were:

- "Kind of misunderstood the double negative questions, but when I read them again it made sense"
- "The question in regards to effective oral hygiene: what does supervised by a dentist mean? Do you mean when a patient attends check-ups regularly?"

Action taken: The researchers acknowledge that the presence of negative items, e.g. "I do not care", which was immediately followed by the 'strongly disagree' option, may make some items difficult to complete. The researchers changed the answer option order so that 'strongly agree' appears first. The researchers also acknowledged the concerns regarding the 'effective oral hygiene regimes question' (question 6) and decided to remove this question from the survey.

Questionnaire length

93% of respondents felt the questionnaire length was 'about right', and one respondent felt it was too long. The mean time to complete, according to the respondent's estimations, was 9.1 minutes (SD=2.99).

Action taken: No action was taken as the majority of respondents felt the questionnaire length was appropriate. Recent research by Revilla *et al.* (2020) has demonstrated that the ideal maximum survey length is between 10 and 15 minutes.

Additional comments

Some respondents left some final comments in free-text form:

- “I didn't like the question with all the descriptive words like "important", "wise" only because I wasn't quite sure which side of the scale was what I wanted as now the scale was displayed vertically as opposed to horizontally”

- “Actually really interested in finding out more about sustainability and environmental issues of dentistry”

- “It was a good topic. More work needs to be done to protect the environment against waste in many industries including dentistry”

Action taken: No action was taken. The survey has been reviewed on both computer and mobile devices, and while the bipolar adjectives scale appears vertically on mobile devices, the ‘top’ and ‘bottom’ options are labelled with the appropriate adjective.

Appendix C – Chapter VIII - Final Survey Items Developed from Previous Literature and *De Novo*

Consent Form (mandatory tick box items)

Taking part in the project:

- I have read and understood the project information sheet
- I have been given the opportunity to ask questions about the project.
- I agree to take part in the project. I understand that taking part in the study will involve completing two questionnaires.
- I understand that my taking part is voluntary and that I can withdraw from the study at any time.

How my information will be used during and after the project:

- I understand that any personal details that I provide will not be revealed to people outside the project.
- I understand and agree that other authorised researchers will have access to this data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information requested in this form.
- I give permission for the anonymous data that I provide to be used in future research.

So that the information you provide can be used legally by the researchers:

- I agree to assign the copyright I hold in any materials generated as part of this project to the University of Sheffield.

Demographics

Please state your personal anonymous identifier code; this should be (free-text response):

1. The first two letters of your mother's first name
2. The number of siblings you have (including half/step-siblings)
3. The number for the day you were born
4. The first two letters of your surname

Please state your gender identity (single answer option):

- Male
- Female
- Non-binary
- Prefer not to say
- Other

Please state your age (free text response)

Please select your programme and year of study (single answer option):

- 1st BDS
- 2nd BDS
- 3rd BDS
- 4th BDS
- 5th BDS
- 1st DH&DT
- 2nd DH&DT

Have you completed any of the following activities related to environmental sustainability in dentistry? (select all that apply)

- Attended a formal teaching session (e.g., lecture/workshop),
- Attended a talk or webinar
- Read a published paper or book chapter
- Encountered the topic in the media
- Other (please specify in the text box below)
- None

Have you completed the FDI World Dental Federation 'Sustainability in Dentistry' MOOC? (single answer option)

- Yes
- No

Have you worked in a dental practice before (excluding work experience)? (single answer option)

- Yes
- No

Awareness of Environmental Sustainability in Dentistry

Five-point Likert scales (reverse): strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.

To what extent do you agree with the following statements:

- **I am aware of the environmental impact of dentistry and oral healthcare….**
- **I am informed about the environmental impacts of dentistry and oral healthcare….**
- **I am knowledgeable about environmental sustainability in dentistry….**
- **I am familiar with environmental sustainability in dentistry …**

These items were developed *de novo* as no relevant previously published items were identified in the literature.

Attitudes towards Environmental Sustainability in Dentistry (measured through Likert scales)

Five-point Likert scales (reverse): strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.

To what extent do you agree or disagree with the following statements:

- **I do not care about the environmental impact of the dental care that I provide**

  Item modified from: Baird HM, Mulligan S, Webb TL, Baker SR, Martin N. Exploring attitudes towards more sustainable dentistry among adults living in the UK. British Dental Journal. 2022 Aug 1;233(4):333–42.

  Original item: I do not care about the environmental impact of dental services

- **I do not care if the dental treatment I provide harms the environment**

  Item modified from: Baird HM, Mulligan S, Webb TL, Baker SR, Martin N. Exploring attitudes towards more sustainable dentistry among adults living in the UK. British Dental Journal. 2022 Aug 1;233(4):333–42.

  Original item: I do not care if my dental treatments harm the environment

- **It is important to me that any dental treatment that I provide does not harm the environment**

  Item modified from: Baird HM, Mulligan S, Webb TL, Baker SR, Martin N. Exploring attitudes towards more sustainable dentistry among adults living in the UK. British Dental Journal. 2022 Aug 1;233(4):333–42.

  Original item: It is important to me that my dental treatments do not harm the environment

- **It does not bother me whether or not the dental care I provide is environmentally friendly**

Item modified from: Baird HM, Mulligan S, Webb TL, Baker SR, Martin N. Exploring attitudes towards more sustainable dentistry among adults living in the UK. British Dental Journal. 2022 Aug 1;233(4):333–42.

Original item: It does not bother me whether or not my dental practice is environmentally friendly

- **It is important to me that the dental profession tries to reduce the impact of dental care on the environment**

Item modified from: Baird HM, Mulligan S, Webb TL, Baker SR, Martin N. Exploring attitudes towards more sustainable dentistry among adults living in the UK. British Dental Journal. 2022 Aug 1;233(4):333–42.

Original item: It is important to me that my dental practice tries to reduce the impact on the environment

- **I do not think that the dental profession should be actively engaged in environmental sustainability**

Item modified from: Durnall O, Martin N, Mulligan S, Dixon J. Environmental sustainability: the attitudes and experiences of UK students in the oral health care profession. British Dental Journal. 2024.

Original item: Do you think that the dental profession should be more actively engaged in environmental sustainability? Yes/No

- **My dental programme should teach me about environmental sustainability in dentistry**

Item modified from: Durnall O, Martin N, Mulligan S, Dixon J. Environmental sustainability: the attitudes and experiences of UK students in the oral health care profession. British Dental Journal. 2024.

Original item: Would you like the undergraduate course to include a greater emphasis on environmental sustainability? Yes/No

- **There is nothing that dentistry can do to reduce environmental issues**

Item adopted without modification from: Agrasuta V, Nelson A. The adoption of green dentistry among dentists in Thailand. Ministry of Public Health Thailand (2013).

Attitudes towards Environmental Sustainability in Dentistry (measured through bipolar adjectives)

5-point radio dial option

Stem: To me, providing environmentally sustainable oral healthcare is…

Important	O	O	O	O	O	**Unimportant**
Useless	O	O	O	O	O	**Useful**
Worthwhile	O	O	O	O	O	**Pointless**
Harmful	O	O	O	O	O	**Beneficial**
Good	O	O	O	O	O	**Bad**
Undesirable	O	O	O	O	O	**Desirable**
Easy	O	O	O	O	O	**Difficult**
Enjoyable	O	O	O	O	O	**Unenjoyable**
Wise	O	O	O	O	O	**Foolish**

The first six items (important/unimportant to undesirable/desirable) were adopted without modification from Baird HM, Mulligan S, Webb TL, Baker SR, Martin N. Exploring attitudes towards more sustainable dentistry among adults living in the UK. British Dental Journal. 2022 Aug 1;233(4):333–42.

The final three items (easy/difficult to wise/foolish) were developed *de novo*.

General Pro-Environmental Attitudes

Five-point Likert scales (reverse): strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.

To what extent do you agree or disagree with the following statements:

- **Compared to other things in my life, environmental problems are not that important to me**
- **Environmental problems are of great concern to me personally**
- **Environmental problems are not that serious because in the long-term things will balance out**
- **I can think of many things that I'd rather do than work toward improving the environment**

These items measure pro-environmental concern and were adopted without modification from: Ellen PS. Do we know what we need to know? Objective and subjective knowledge effects on pro-ecological behaviors. Journal of Business Research. 1994 May 1;30(1):43–52.

- **I think of myself as someone who is very concerned with environmental issues**
- **I think of myself as an environmentally friendly consumer**
- **I would not want my family or friends to think of me as someone who is concerned about environmental issues**
- **I would be embarrassed to be seen as having an environmentally friendly lifestyle**

These items measure pro-environmental identity and were adopted without modification from: Whitmarsh L, O'Neill S. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. Journal of Environmental Psychology. 2010 Sep 1;30(3):305–14.

Knowledge of Environmental Sustainability in Dentistry

All items to measure 'knowledge of environmental sustainability in dentistry' were developed *de novo* due to an absence of previous research items.

5-option single best answer questions.

The single best strategy to make dentistry more environmentally sustainable is:

- Recycle more single-use plastics
- Perform minimally invasive procedures
- Focus on the prevention of oral diseases
- Use eco-friendly materials
- Stop using dental amalgam

Which option is the most significant contributor to the environmental impacts of dentistry and oral healthcare:

- Waste production from the dental surgery
- Energy and water consumption during treatment
- Nitrous oxide release from inhalation sedation delivery
- Patient travel and staff commute to the dental surgery
- Procuring/buying materials, clinical items and equipment

Which of the following most accurately reflects the use of single-use plastics (SUPs) in dentistry:

- Cross-infection control policies encourage the use of SUPs in dentistry
- SUPs are not necessary and can be avoided in all areas of clinical practice
- SUPs can be recycled with appropriate waste segregation streams
- The use of SUPs in dentistry facilitates a circular economy
- SUPs are more environmentally sustainable than most reusable alternatives

What is the primary concern associated with the use of amalgam fillings?

- High energy consumption during production
- Less conservative tooth preparation
- Release of mercury into the environment
- Risks of harm to human health
- Generation of non-biodegradable waste

What is the primary environmental benefit of using digital radiography in dentistry?

- Reduced water consumption
- Elimination of chemical waste
- Reduced single-use plastics
- Lower energy usage
- Decreased paper waste