IMPLEMENTING ENVIRONMENTAL SUSTAINABILITY EDUCATIONAL INTERVENTION IN DENTAL HYGIENE INSTRUCTION

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ABSTRACT

Wai-Sum Leung; Implementing Environmental Sustainability Educational Intervention in Dental Hygiene Instruction
(Under the direction of Elizabeth Kornegay)

The healthcare industry, including dentistry, supplies a large portion to waste output, a contributing factor to climate change which threatens public health. The purposes of this study were to determine the baseline attitudes and knowledge of dental hygiene (DH) students towards environmentally sustainable dentistry (ESD), implement an educational intervention and assess its impact on the DH student's baseline attitudes and knowledge. Thirty-four second-year DH students at the UNC-CH Adams School of Dentistry (ASoD) were recruited for this one-time educational intervention study that utilized survey methods containing quantitative and qualitative elements. Data was evaluated with paired t-tests, univariate, bivariate and qualitative analyses. Participant's level of knowledge and attitude towards ESD was significantly higher ($p < 0.0001$) following the study intervention. This educational intervention raised awareness an knowledge of ESD among dental hygiene students. Dental hygiene educators should consider incorporating ESD into the DH curriculum to minimize dentistry's environmental impact and promote public health.

To my parents, who chose a harder life in order to give me a better one. Thank you for all of your love, support and prayers as God has guided me on this journey. 感谢父母为我做的一切， 多谢你们一路来都支持我， 鼓励我和为我祷告。最重要的是多谢你们教会我这么做一个爱神的基督徒。

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LIST OF ABBREVIATIONS AND SYMBOLS

ADA	American Dental Association
ADEA	American Dental Education Association
ASoD	Adams School of Dentistry
BDA	British Dental Association
Btu	British Thermal Units
CAL FIRE	California Department of Forestry and Fire Protection
CLEAN	Climate Leadership & Environmental Action Network
CSH	Centre for Sustainable Healthcare
DH	Dental Hygiene
DSC	Disposable Sharps Container
ED	Epizootic Shell Disease
ESD	Environmentally Sustainable Dentistry
GHG	Greenhouse Gas(es)
IPCC	Intergovernmental Panel on Climate Change
IPE	Interprofessional Education
IRB	Institutional Review Board
LLUH	Loma Linda University Health
MT	Metric Ton
NHS	National Health Service
NO	Nitrous Oxide
OECD	Organization of Economic Co-operation and Development
RSC	Reusable Sharps Container

SD	Standard Deviation
SHE	Sustainable Healthcare Education
SLR	Seal Level Rise
UK	United Kingdom
UNC-CH	University of North Carolina at Chapel Hill
US	United States
WHO	World Health Organization
WR	Waste Rubber
±	plus or minus

CHAPTER 1: INTRODUCTION AND REVIEW OF THE LITERATURE

Introduction

The United States (US) healthcare system is one of the largest major waste emitters on the planet.[1] The US healthcare system includes laboratories, hospitals, private medical clinics and dental offices or institutions. These organizations contribute to waste output through purchasing products, including consumable materials, and directly emitting greenhouse gases as well as various types of medical wastes that become land and water pollutants.[2] This waste creates direct and indirect threats to human, animal, and environmental health. [3] Waste is also a contributing factor to climate change, one of the biggest challenges facing the current and future generations.[3] The effects of climate change threaten the food, water, home, and health security of millions of people across the world.[4] Action must be taken to mitigate and reverse climate change.

Dental care professionals have an ethical obligation and responsibility to better understand and minimize the dental profession's environmental and public health impact.[5] In 2017, the Fédération Dentaire Internationale (FDI) World Dental Federation, the leading organization representing dentistry in the world, issued the following statement: "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 well-being for all through all stages of life." [6] Dental organizations across the globe reflect their support of environmentally sustainable dentistry (ESD) through their policies, education, and management practices. For example, the British Dental Association (BDA) has collaborated with the United Kingdom's (UK) Centre for

Sustainable Healthcare (CSH) to create a guide for dental teams that want to transform their practices to be more environmentally sustainable.[7, 8] Other than helping to create this guide, the CSH institution is also dedicated to incorporating sustainable healthcare in education, research and practice. One of the initiatives created by the CSH includes the Sustainable Healthcare Education (SHE) network. SHE is an interprofessional coalition of over 900 clinicians, academics and students aiming to incorporate sustainable healthcare education into health profession curriculum and general education.[9]

Presently, there is no US based equivalent of CSH that focuses on interprofessional environmental sustainability education. Existing organizations are focused primarily on internal medicine and there is no mention of dentistry, despite dentistry being a billion-dollar medical industry within the US.[10 -11] Education on the impact of climate change and environmental sustainability is vital in preventing adverse health outcomes related to the environment and promotes healthier communities. However, resources for ESD education in US-based dental and dental hygiene curriculum are sparse and their effectiveness is unstudied. There is also limited research and knowledge on the general knowledge, reception, and attitudes of dental professionals towards ESD.

The purpose of this study was to assess the knowledge, attitudes, and beliefs that Dental Hygiene (DH) students at the Adams School of Dentistry (ASoD) at the University of North Carolina at Chapel Hill have towards environmentally sustainable dentistry before and after an asynchronous online educational module intervention. Additionally, the study intends to evaluate the usefulness of this online asynchronous module learning to contribute insight on future development of online educational resources for DH students.

Review of Literature

Earth's Climate

Since the mid- to late- 1900's, the earth's climate has been warming at an unprecedented rate.[12] Prior to 1880, the planet's surface temperature increased by 0.07°C per decade; however, from 1881 to 2018, the average increase of temperature per decade more than doubled from 0.07°C to 0.17°C.[13] Recent years have consecutively been the warmest years ever recorded by humans with 2014 as the warmest year prior to 2015 and onward.[14] There are no indications that this increase of temperature is caused by natural variations in the environment.[14] Rather, the Intergovernmental Panel on Climate Change (IPCC) found that it is 95% probable that human activity is the predominant cause behind the increase in Earth's surface temperature.[15] Human activities that contribute to the change in Earth's temperature include, but are not limited to, the emissions of greenhouse gases (GHG), such as carbon dioxide and nitrous oxide, from combustion of fossil fuels, deforestation, and land-use change.[14] Based on current models, even if GHGs emissions stabilized immediately, it would still take several decades for atmospheric warming to halt.[14] Continued changes in the Earth's climate due to anthropologic causes are unsustainable for human societies and future generations due to threats to habitable environments, food security and socioeconomic wellbeing.

Consequences of Climate Change

Precipitation

Precipitation, a deposit on the earth of hail, mist, rain, sleet, or snow, in the US has increased since 1900.[16-17] The increase in precipitation is unequally distributed, where some areas see higher volumes of precipitation, while others experience a decline in precipitation.[16] Areas that were previously dry are becoming drier and others that were wet are becoming

wetter.[17] Consequently, the difference in regional climate has widened and drifted towards extremes of each end of the weather spectrum with increased incidences of natural disasters such as droughts, heat waves, wildfires, flooding, and heavy storms.[18]

In times when natural disasters strike, households are faced with health risks from factors such as personal injury, housing instability, and sudden financial obligations.[19] The negative impacts of natural disasters extend beyond the individual and into the community support system as well. These impacts include effects to jobs, school closures, damage to vital services such as water, and electricity supplies may be affected.[19] In particular, flooding in the US has resulted in 4,586 lives lost between 1959 – 2005.[20] Property and crop damage cost an estimated 8 billion dollars every year from 1981 to 2011 in the US.[21]

As some areas suffer from increased flooding, others experience the opposite. The California Department of Forestry and Fire Protection (CAL FIRE) attributes the increasingly severe and deadly fire season in California to climate change.[22] The decrease in precipitation coupled with hot temperatures increase the risk of wildfires as the moisture in plants and soil is evaporated; thus, becoming the perfect kindling for fires.[22] CAL FIRE reports that the fire season has increased by approximately 75 days, with a 5-fold increase in wildfires from 1972 to 2018.[23] According to another report by CAL FIRE, 6 of the 20 most destructive California wildfires in history occurred in the year 2020.[24]

Another major concern is food insecurity. Due to increased frequencies of natural disasters from changes in precipitation, food security is a growing concern for those impacted. Food insecurity has long lasting health impacts that include malnutrition, increased risk of cardiovascular disease, decline in physical and mental health, restricted activities, and lowered immune systems with increased risk for infections and development of chronic conditions.[19]

Other than the direct physical and financial burdens caused by natural disasters, stressors that come with coping with natural disasters can also cause more subtle mental and physical health risks as well. Studies have found that at least half of those who are directly or indirectly impacted by natural disasters, such as Hurricane Harvey, require clinical care for mental health.[25]

Warming Ocean Waters

The ocean acts a thermoregulator for the planet's atmosphere.[26] It helps to distribute heat around the planet through ocean currents, counteracting uneven heat distribution and making it possible for areas such as the north and south poles habitable for humans.[27] The ocean also produces over half of the oxygen necessary for life and stores carbon and other greenhouse gases found in the atmosphere as well as excess atmospheric heat.[28-29] Due to climate change, ocean surface waters have warmed around 0.7 C globally from 1900 to 2016.[29] Seemingly small changes in the ocean can have significant negative effects on, not only the climate, but also on factors such as water quality, energy and transportation, socioeconomic/job stability and human health. The next few subsections of this paper will further explore the ties between ocean, warming sea waters and the factors listed above. The connection between warming ocean waters and rising sea levels will be discussed first.

Rising Sea Levels

Increased ocean temperature will cause rising sea levels through several ways. One of the major ones is thermal expansion. Thermal expansion is the general increase in volume of water itself as ocean temperatures increase.[30]1/3 of global sea-level rise since 2004 is attributed to thermal expansion.[30] Warming ocean waters also cause sea level rise through the melting of ice shelves and reduced sea ice coverage.[31] If the entirety of the Antarctic Ice Sheet were to melt all at once, then sea levels would rise more than 180 feet.[32] While this has not occurred yet, there is

a steady decline in ice sheet cover on Earth and rising sea levels as a result. Coastal communities are already experiencing the effects and costs of climate-change induced sea level rise (SLR). Consequences of SLR include an increase in flooding, decline in species biodiversity, saltwater intrusion, and miles of coastal erosion.[33-35] These consequences deal a heavy financial blow to the economy and pose risks to both public and environmental health. In the US, coastal erosion results in the loss of around $500 million in property loss and management of coastal erosion costs another $150 million a year.[36] Other than the financial burden, coastal erosion also damages the environment and public health through saltwater intrusion. Saltwater intrusion is the contamination of ground freshwater by saltwater, causing that freshwater to be unusable for human and animal consumption or irrigation.[37] The change of ground freshwater to saltwater also results in inhabitable conditions for local flora.[37-38]

Florida is considered one of the most vulnerable areas to SLR due to low-lying areas and its proximity to ocean currents.[39] The average sea level in Key West, Florida has risen around 9 inches over the past century, which is slightly higher than the 6.69 – 8.27 global SLR average.[40] It is projected that SLR in Southeast Florida will be 6 inches by 2030, 14 inches by 2060, and 31 inches by 2100.[40] Additionally, due to SLR and other climate change implications, Florida is at risk for the spread of illnesses such as Zika virus, increase in invasive species and damage to coral reefs.[39, 41]

Communities and countries outside of the US are also being affected by SLR. One of these areas is the nation of Kiribati. Kiribati is made up of a conglomeration of coral atolls and reef islands within the Pacific Ocean.[42] Sitting at just six feet above sea level, Kiribati and its people are especially vulnerable to the effects of climate change and rising sea levels.[42] During times of strong storm surges, costs to repair infrastructure and other financial losses can total up

to US $430 million.[43] These costs will likely only go up if nothing is done to reverse the damage. The previous president of Kiribati, Anote Tong, and the government of Kiribati have pushed for the relocation of Kiribati's citizens with the movement "migration with dignity".[42] The government purchased around 6,000 acres of land on the island nation of Fiji as a potential refuge.[42]

Ocean Resources

Warming surface temperatures of the ocean from climate change also negatively influence the ocean's role as a vital source of food, energy, transportation, and medicine, which forms the backbone of numerous national and local economies.[44] Specifically, in the United States, the ocean is responsible for around 76% of transportation, employs around 3 million people, and produces $282 billion in goods and services.[45]

Variations in water temperature result in changes to the aquatic microbiome, fundamental physical and chemical composition, as well as current patterns, which contribute to the changes of precipitation discussed in the previous section.[46] The concentration of oxygen in ocean water is also lower as warmer water holds less oxygen. Lower oxygen concentrations in the ocean can result in dead zones devoid of aerobic organisms and have profound effects on extremely complex marine food webs that humans rely on.[47] For example, the catch potential for fisheries is projected to decline in warmer areas while other areas are estimated to see an increase in catch potential, such as the Gulf of Alaska where it is expected to increase by around 10%.[48] While certain areas like the Gulf of Alaska may benefit from the effects of climate change, others such as the New England fishing industry, are not as fortunate. New England has seen a decline in its fisheries due to increase in ocean water temperatures.[49]

Other than driving migratory fish north into cooler waters, there are also concerns that

warmer waters may cause an increase in zoonotic diseases that can harm marine life and fisheries.[50] An example of this is epizootic shell disease (ED) seen in the American lobster.[50] The local lobster population of southern New England has been decimated by ED, which damages the cuticle of lobsters and increases their mortality rate when they shed their exoskeleton.[51] Warmer waters will be favorable for ED proliferation, further harming southern New England lobster populations and the local fisheries.[50] As seen from this example, the changing climate and water temperatures can pose various management challenges to local fishing industries as they try to adapt.[50]

Healthcare Waste

As previously stated, climate change is largely affected by emissions of GHG from fossil fuel combustion, deforestation, and land-use change. Within the U.S, the healthcare field plays a large part in the activities that contribute to the national air, water, and soil waste output.[52] A hospital, for example, is the second most energy-intensive commercial buildings in the country, after food service facilities.[54] In 2013, hospitals used about 225 thousand British thermal units (Btu) while food service buildings were at around 275 Btu.[54] A Btu is defined as the amount of heat required to raise the temperature of one pound of water by one-degree Fahrenheit.[55] The hospital's high energy use comes variables such as constant use of the building and various high energy demanding specialized medical equipment.[54] Some other aspects of US healthcare that play into its environmental impact include using energy-intensive goods and services (i.e. pharmaceuticals and medical devices) and the manufacturing of these goods.[52] Figure 1 outlines how actions like consumption, transportation and disposal of goods adds to waste output and climate change.[53]

The US healthcare industry also contributes a significant portion to the gross national

carbon footprint. In 2011, the U.S. healthcare industry emitted 655 million metric tons (MT) or 2205 lb.[55-56] This was the equivalent of 10% of the total amount of carbon emitted in the U.S. for 2011.[55] If the U.S healthcare sector was regarded as a country, then it would rank as the world's seventh largest producer of carbon dioxide.[55] More recently, Pichler, Jaccard et. al conducted an international comparison of health care related carbon footprints from member countries of the Organization of Economic Co-operation and Development (OECD).[1] To calculate the national carbon footprint, the EE-MRIO Eora (v199.82) was used in combination with national health care expenditure data. Carbon emissions used in the calculation include those generated by purchases and services of the healthcare sector, ambulatory services, long-term and preventative care etc.[1] They found that the US healthcare industry emitted 479.7 MT, contributing 7.9% to the nation's carbon footprint in 2014, placing it in second place after China (which emitted 600.6 MT) as the largest emitter of healthcare related carbon emissions.[1] Japan was the third largest emitter of healthcare related carbon emissions in the world, emitting 114.9 (MT).[1]

Dental Waste

Since dentistry is a major part of the medical industry within the US, it is vital to understand the role that dentistry plays in healthcare waste on a local and national level. According to the American Dental Association (ADA), there are 200,419 dentists working in dentistry in the U.S as of 2019.[57] This translates to about a 61.1 dentists per 100,000 people in the U.S.[57] The dental industry is also projected to grow as disposable income in patients rises and unemployment rates lower; industry revenue is estimated to increase 2.2% annually to $142.6 billion in 2020.[58] Following this trend of growth, one can expect to see a similar trend in number of procedures performed and materials needed; thus, the environmental impact of the dental industry will also grow. Dental related waste that is expected to increase include but are not

limited to dental amalgam, silver, lead, other biomedical waste, and GHGs.[2] The following subsections will explore the relationship between these types of waste and the environment.

Dental Amalgam

Dental amalgam, also known as "silver fillings", are widely popular in the United States. According to the ADA, dental amalgam fillings have been used in the mouths of more than 100 million Americans.[59] Compared to other types of dental fillings, such as tooth colored composite fillings, dental amalgam fillings have a much lower failure rate, are less technique sensitive, and are cheaper.[60-65] This makes dental amalgam restorations desirable for people with lower income who cannot afford composite fillings and work to bridge oral health disparities.

Numerous studies over the years have not identified any negative health outcomes on the average patient from dental amalgam/mercury.[62] Most of these studies were focused primarily on the effect of dental amalgam in the human mouth and displayed little consideration for environmental health. Despite the benefits of amalgam fillings, it is important to consider other direct and indirect risks that these fillings may pose to human and environmental health. Attention to how dental amalgam waste may indirectly affect human health was neglected until recent years.[63]

Dental amalgam is mostly composed of liquid mercury.[62] A 2013 assessment conducted by the United Nations Environment Programme found that dental mercury contributes to 10% of global mercury consumption.[63-64] Waste products from placement and removal of dental amalgam include elemental mercury vapor, dental amalgam scrap, amalgam waste, and amalgam sludge.[65] While safety measures are in place to capture dental amalgam/mercury waste, these are not completely effective.[2] Chairside traps for amalgam removal from dental wastewater have been found to be 68% effective and an average vacuum filter is approximately 40% effective.[65]

Around 2/3rds of all dental mercury eventually finds its way into the environment where it can negatively impact human, public, and environmental health.[2]

Once dental mercury is released to the environment, it can be converted to methylmercury by aquatic microorganisms.[65] Human exposure to methylmercury can have toxic and even fatal effects ranging from threat to the development of children in utero, damage to the nervous, digestive, and immune systems, and on lungs, kidneys, skin and eyes.[65-66] The current World Health Organization (WHO) recommendations urge for phasing down on the use of mercury containing products like dental amalgam due to environmental and public health concerns.[66] WHO recommends the introduction of non-mercury containing alternatives instead.[66] However, elimination of mercury containing products such as dental amalgam is problematic in countries such as the US where healthcare is funded by a mix of public and private, for-profit, and nonprofit insurers.[67] Certain socioeconomic groups have limited access to oral health treatment due to cost and other social determinants of health.[68] Dental amalgam is vital in bridging oral health disparities due to its lower cost and effectiveness.[60, 64]

Greenhouse Gases (Carbon Dioxide & Nitrous Oxide)

Carbon dioxide and other greenhouse gases such as nitrous oxide (NO) perform the important function of trapping heat in the atmosphere.[69] This warms the planet and allows life to thrive; however, excess amounts of GHG have resulted in the overheating of the planet.[70] In dentistry, some prominent GHG emitted are carbon dioxide and nitrous oxide. Duane et al. estimated the carbon footprint of primary dental practices in England by aggregating the carbon emissions from staff travel, patient travel, energy, water, and procurement of necessary materials and services to run a dental office from April 2013 to March 2014.[71] The data was obtained through secondhand sources (Business Services Authority, Health and Social Care Information

Centre, and National Association of Specialist Dental Accountants) and converted with factors from the Department of Agriculture and Rural Affairs as well as the Small World Consulting Ltd.'s carbon calculator.[71]

The study found that the carbon footprint of primary dental practices made up 3% of the National Health Service (NHS) carbon footprint in England.[71] This was further broken down by evaluating the amount of carbon emitted from specific procedures. Basic dental examinations had low individual emissions of greenhouse gases of 5.50 kgCO2e but occurred frequently.[71] (CO2e is how a collection of GHGs is denoted and signifies the amount of CO2 that would have the equivalent global warming impact[72]). Therefore, examinations were 27.08% of the total carbon footprint of dental services.[71] More intensive procedures, especially those that used nitrous oxide, had larger individual carbon footprints but occurred less frequently. Metal denture work, for example, had an individual carbon footprint of 70.52 kgCO2e but only made up 0.85% of the total carbon footprint for dental services.[71]

Nitrous oxide, more commonly known as laughing gas, is used in dental and medical procedures as a mild sedative.[73] Procedures that utilize nitrous oxide possess a heavier carbon footprint because nitrous oxide outstrips carbon dioxide in global warming potential by 300 times and damages the protective ozone layer in Earth's atmosphere.[74] Globally, 40% of nitrous oxide emissions stems from human activity.[69] In 2017, about 5.6% of all U.S. greenhouse gas emissions stemmed from human activities.[75] One method to reduce the emission of nitrous oxide by dental practices is to utilize technology that can capture and neutralize nitrous oxide as it is being used. This method is used in some hospitals but is not widespread due to lack of publicity and associated costs.[71]

Waste Incineration

Medical waste is waste that may be contaminated by blood, body fluids, or other potentially infection material. As a result, sterilization of this waste is required to avoid the spread of infection and serious diseases.[76] Medical waste is usually generated by hospitals, dental practices, blood banks, and other establishments that work with blood and bodily fluids.[75] Prior to 1997, this type of waste was 90% incinerated to avoid the spread of infection and serious diseases.[76] Although these incinerators may follow the tolerable air quality guidelines set by individual countries, the public can still experience negative effects. For example, Viel et al. conducted a study in France that found that population living near incinerators had an increased risk of non-Hodgkin lymphoma and serum organochlorine concentration.[77] Consequently, alternative methods to incineration have been developed such as microwave technologies or steam sterilization prior to landfill disposal.[76]

Dental Sustainability

Laws & Policies

Healthcare providers should be leaders in adopting environmentally sustainable practices to reduce their waste, minimize their environmental impact, and protect public health. Environmental sustainability must be implemented on the industrial and individual level across all sectors to be effective. In accordance with the FDI's statement on ESD, dental professionals and organizations have collaborated, debated, and passed initiatives and policies that work towards a sustainable future that considers the needs of the present and future. For example, the Minamata Convention on Mercury is a global treaty that aims to reduce usage and exposure of mercury in order promote public and environmental health.[78] It was agreed upon in Geneva, Switzerland on Saturday, 19 January 2013 and entered into force on 16 August 2017.[78] As part of

the treaty, countries like the UK have begun to phase out the use of mercury and dental amalgam.[79] As of July 2018, dental amalgam was no longer used in children, and pregnant and breastfeeding women in the UK.[67, 71, 80]

Additionally, the United Kingdom passed the 2008 Climate Change Act in response to the effects of climate change.[80] The UK government, including the NHS England dental teams[71], committed to reducing greenhouse gas emissions by at least 100% of 1990 levels by 2050.[78] The Sustainability Development Unit of England NHS estimated that these measures have resulted in cumulative savings for energy saving measures of around $2.44 billion over the past decade and will continue to save billions more in the decades to come.[81-82]

While the dental profession across the world is making great strides to a sustainable future, the US in comparison lags behind. This is partly due to the politicization of climate change and environmental protections. During the presidential election that occurs every four years, opposing political party candidates often have opposing views on the management of climate change. In 2015, the Obama administration passed similar legislation to the UK's 2008 Climate Change Act. It was called the Clean Power Plan of 2015. The Clean Power Plan invested in renewable and sustainable energy such as solar and wind.[83] It also set state carbon emission reduction targets and aimed to lower national electricity sector emissions by 32% below 2005 levels by 2050.[81] However, this legislation was unraveled by the Energy Independence Executive Order (13783) from former president Donald Trump.[83] From 2016 – 2020, many other environmental health measures and climate change actions have also been scaled back by the Trump administration; such as the withdrawal from the Paris Climate Change agreement.[85] The Paris Climate Change Agreement is another international treaty whose goal is to limit global warming to below 1.5 – 2 degrees Celsius compared to pre-industrial levels.[86] Most recently, the

newest executive cabinet has implemented a widespread agency review to reverse measures that may threaten public health and the environment as well as rejoin the Paris Climate Change Agreement.[87] The volatile nature of US politics and the politicization of climate change and associated issues are an obstacle to adopting effective and long-term environmental protection and sustainability measures.

Practicing Dental Sustainability

Despite the instability of laws and policies related to climate change and environmental sustainability in the US, practicing dental sustainability is easily achievable without compromising patient safety. Much of dental related waste can be managed and reduced with the traditional 3 R's: reduce, reuse, and recycle. Reduction can be achieved by practicing sustainable procurement of products. Sustainable dental procurement is the practice by which the dental surgery addresses environmental, social and ethical considerations when purchasing goods or services.[88] Purchasing what is needed while minimizing excess stock reduces waste produced from expired products and can also be cost beneficial. In NHS England, wasteful procurement was 19% of the dental carbon footprint.[88] Dental institutions and clinics can also practice stock rotation, a method commonly used in grocery stores and other retailers. It is a system to reduce waste by moving older products to the front and place new stock in the back.[88]

The next "R" is reuse. This practice can be achieved by using products such as reusable sharps containers. In 2018, McPherson et al. conducted a case study examining the impact of greenhouse gases of nation-wide transport distances when a large US hospital converted from disposable sharps containers (DSC) to reusable sharps containers (RSC).[89] The study found that by converting to reusable sharps containers (RSC), the hospital, Loma Linda University Health (LLUH), reduced its annual greenhouse gas emissions by 162.4 metric tons carbon dioxide

equivalent.[89] Furthermore, it reduced 50.2 tonnes of plastic DSC and 8.1 tonnes of cardboard from the sharps waste stream.[89] This saved 31.8 tonnes of potential waste from the landfill and 18.4 tonnes from incineration.[89]

Last, but not least, among the "R"s is recycle. Products such as nitrile gloves and lab plastics can be recycled through the manufacturer or other institutions.[90] For example, VWR and Kimberly Clark are manufacturers that offer recycling options for their nitrile gloves at the University of North Carolina at Chapel Hill. This is not possible for biohazardous waste but can be done with gloves used in labs. Additionally, Fischer Scientific is working with UNC Green Labs to implement the recycling of plastic film that comes with packaged items. If it is successful, then they will try to spread the practice to more UNC facilities.[90] The availability of recycling is important because waste rubber (WR) is harder to reprocess compared to plastics. WR is a thermoset material; material that has been irreversibly hardened by curing process.[91-92]

Practicing dental sustainability is easily achievable and can be cost-efficient in the long run. Following the three "R's" and practicing seemingly small steps such as sustainable procurement and sourcing of materials can make a big difference in minimizing environmental impact and prioritizing public health. However, this information is not widely available or taught in the dental field. To prevent adverse health outcomes related to climate change and prioritize public health, dental and dental hygiene education should incorporate environmental sustainability in its curriculum. The inclusion of environmental sustainability in dental education can be helpful in standardizing the practice of ESD.

Sustainable Dental Education

As mentioned previously, the CSH works to incorporate interprofessional sustainable healthcare in education, research and practice. Other than the SHE network, the CSH has also

created a Fellows and Scholars program for clinicians and students.[93] The mission of this program is to provide scholars and fellows a unique opportunity to: "learn about sustainability, develop skills in leadership and quality improvement, and contribute to the new sustainability dimension of healthcare".[93] Members of the Fellows and Scholars program are from a wide range of backgrounds – ophthalmology, psychiatry, surgery, general medicine, dentistry, and dental public health.[93]

The closest equivalent to the CSH in the US is the Medical Society Consortium on Climate and Health.[94] This organization's mission is to: "organize, empower and amplify the voice of America's doctors to convey how climate change is harming our health and how climate solutions will improve it."[94] The consortium has chapters all over the country and has member societies from a wide range of backgrounds. Member societies include the American Academy of Allergy Asthma & Immunology, the American Academy of Family Physicians, the American Academy of Pediatrics etc.[94] The North Carolina based chapter of the consortium, Clean Air Carolina, partnered up with the recently founded Climate Leadership & Environmental Action Network (CLEAN).[95] The mission of CLEAN is to collaborate with UNC School of Medicine faculty to incorporate clinically-relevant content about health impacts of climate change and pollution in the curriculum for first- and second-year medical students.[95] They are also working with Clean Air Carolina, the NC-based chapter of the Medical Society Consortium on Climate and Health to build a state-wide network of clinicians, trainees, and other professionals involved in the movement for climate action and health equity in North Carolina.[95]

Despite their numerous member societies and affiliates, dentistry is nowhere to be seen even though it plays pivotal role in US healthcare. Overall, there is little research and knowledge on US based ESD in practice and in education. The ADA provides a resource on their website

that is titled “80 Ways to Make Your Dental Practice Green”.[96] While this list is a starting point, it is not comprehensive and lacks detail on the “how” when implementing ways to make a dental practice green. For example, one of the ways listed is “Get rid of aerosol products” but does not provide details on alternative products.[96] There is also no way to determine how many offices have utilized this list measure its impact. This resource is not sufficient for promoting the practice and standardization of ESD. To implement ESD on a wider scale, incorporation of sustainable dentistry into the core curriculum of dental and dental hygiene instruction may be useful. It has the potential to reshape the field of dentistry and opens a lot of opportunities for interprofessional education (IPE) opportunities. Dental, dental hygiene, and other allied health science students and faculty could work together to build relevant sustainability education into the core curriculum of healthcare.

There is a growing need to learn more about sustainable practices in dentistry and how education can play a role in ESD. A research project presented at the 2021 American Dental Education Association’s (ADEA) annual conference by Lee et al. reported that dental students and instructors from the Harvard School of Dental Medicine and the Institute of Dentistry of Queen Mary University of London were surveyed to evaluate their knowledge and attitudes towards ESD.[97] Study results found that both dental students and educators were interested in implementing ESD into dental education.[97] However, barriers to implementation of ESD in US and UK based dental education include lack of ESD educational materials and knowledge about ESD.[97] To overcome these challenges, Lee et al. propose provision of ESD-related learning outcomes and creating capacity for educator to work on embedding ESD in dental education.[97]

This study recognized the same barriers to implementation of ESD in US dental education. Thus, an online educational module and follow-up assignment was designed, created,

and implemented in this study. While this study also evaluates knowledge and attitude, it focuses on 2nd year dental hygiene students from the Adams School of Dentistry in Chapel Hill, as well as, evaluates the usefulness of the online interactive educational module in improving knowledge and attitudes towards ESD.

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CHAPTER 2: IMPLEMENTING ENVIRONMENTAL SUSTAINABILITY EDUCATIONAL INTERVENTION IN DENTAL HYGIENE INSTRUCTION

Introduction and Review of the Literature

The United States (US) healthcare system is one of the largest waste emitters on the planet.[1] The US healthcare system contribute to waste output through purchasing products, including consumable materials, and directly emitting greenhouse gases as well as various types of medical wastes that become land and water pollutants, as Figure 1 depicts.[2] This waste contributes to climate change and creates threats to human and environmental health. [3] Climate change is one of the biggest challenges facing the current and future generations; it has threatened the food, water, home, and health security of millions of people across the world.[4]

Dental care professionals have an ethical obligation and responsibility to better understand and minimize the dental profession's environmental and public health impact.[5] In 2017, the Fédération Dentaire Internationale (FDI) World Dental Federation, the leading organization representing dentistry in the world, issued the following statement: "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 well-being for all through all stages of life." [6] Dental organizations across the globe reflect their support of environmentally sustainable dentistry (ESD) through their policies, education, and management practices. For example, the United Kingdom's (UK) Centre for Sustainable Healthcare (CSH) is dedicated to incorporating sustainable healthcare in education, research and practice.[7,8] One of the initiatives created by the CSH includes the Sustainable Healthcare Education (SHE) network.[9] SHE is an interprofessional

coalition of over 900 clinicians, academics and students aiming to incorporate sustainable healthcare education into health profession curriculum and general education.[9]

Presently, there is no US based equivalent of CSH. Existing organizations are focused primarily on internal medicine and there is no mention of dentistry, despite dentistry being a billion-dollar medical industry within the US.[10 -11] Education on the impact of climate change and environmental sustainability is vital in preventing adverse health outcomes related to the environment and promotes healthier communities. However, resources for ESD education in US-based dental and dental hygiene curriculum are sparse and their effectiveness is unstudied. A research project presented at the 2021 American Dental Education Association's (ADEA) annual conference by Lee et al. reported that dental students and instructors from the Harvard School of Dental Medicine and the Institute of Dentistry of Queen Mary University of London were surveyed to evaluate their knowledge and attitudes towards ESD.[12] Study results found that both dental students and educators were interested in implementing ESD into dental education.[12] However, barriers to implementation of ESD in US and UK based dental education include lack of ESD educational materials and knowledge about ESD.[12] To overcome these challenges, Lee et al. propose provision of ESD-related learning outcomes and creating capacity for educator to work on embedding ESD in dental education.[12] This study recognized the same barriers to implementation of ESD in US dental education and created an online educational module on ESD as the study intervention. The specific aims of this study were the following:

1) Determine the baseline for DH student's attitudes and perceptions towards environmentally sustainable dentistry.
2) Determine the usefulness of an educational intervention in dental hygiene instruction on environmentally sustainable dentistry

Methods

Recruitment

Recruitment for this study included the second-year dental hygiene students (N=34) enrolled at the University of North Carolina at Chapel Hill (UNC-CH) Adams School of Dentistry (ASoD) for the fall semester of 2020. Second-year DH students were recruited as they have completed at least one year of clinical work with patients and likely witnessed how dentistry can impact the environment.

Research Design

This study was completed in two phases. Phase one utilized an educational online module intervention paired with immediate pre- and post-surveys. The surveys and module were open for a period of two weeks. Three weeks after the closing of phase one, phase two employed a follow-up assignment and a post-assignment survey for the study participants. Figure 2 outlines the flow and design of this study.

Completion of the module and assignment were mandatory for second-year dental hygiene students, while completion of the study surveys was voluntary. Students that complete the module and assignment but chose to not participate in the study were not considered part of the study. The UNC-CH Institutional Review Board (IRB) determined this study was exempt (20-1313).

Module Survey Instrument

Second-year DH students from the UNC ASoD completed a pre- and post-survey, which contained questions on attitudes, knowledge, and receptiveness towards climate change and environmentally sustainable dental practices. The surveys were given immediately before and after the completion of an online educational asynchronous module. The surveys were pilot

tested for face validity by three dental hygienists and three dentists who had graduated within the past three years. Pilot testers provided feedback on aspects such as time needed to complete the study, comprehension and clarity of survey questions. Each survey was designed to take no more than 3 minutes to complete.

Study participants were assigned a random ID number in the pre-survey (Appendix A) generated by Qualtrics to track and measure changes in knowledge and attitudes from pre- and post-survey responses. The random ID also ensured that survey responses remained anonymous. Survey responses and module participation were kept separate with no linkages. The pre-survey consisted of 6 questions focused on knowledge regarding current environmental affairs and 7 questions on attitudes and beliefs regarding climate change, as well as the extent to which environmental sustainability is related to the dental field. Questions utilized a mixture of multiple-choice knowledge-based and Likert-style questions ranging from strongly disagree to strongly agree. For example, question 11 in the pre-survey asked, “Please indicate your level of agreement with this statement: Environmental sustainability is important.”

The post-survey (Appendix B) link was embedded in the educational module. Study participants could not access the link until they completed the module. Module completion was determined with answering all questions embedded in the module, which helped ensure that participants successfully completed the module prior to accessing the post-survey. Survey participants filled in their randomly generated pre-survey ID number once they started the post-survey to provide linkage between pre- and post-survey responses. The post-survey consisted of 6 knowledge questions and 7 attitude questions that mimicked that of the pre-survey with the addition of 2 Likert style questions that asked participants for their opinion of the module as well as a free response option at the end of the survey that allowed for any feedback not covered by

the survey.

At the completion of the post-survey, study participants had the option to opt in for an equal chance to receive a $15 Amazon gift card by providing their name and email address.

Module

The same pilot testers for the pre- and post-surveys also pilot tested the module to mimic the study experience as closely as possible. The educational module was tested for ease of use, time to complete, and accessibility. Pilot testers were given same access permissions as students and timed themselves while completing the module.

The online educational module was titled “Environmental Sustainability and Dentistry”. It was hosted on the UNC-CH Learning Management System (Sakai) and comprised of 6 sections: Environmental Sustainability, Climate Change Impacts, Healthcare & Dentistry, Sustainable Laws & Policies, Applications, and References. Materials in the module were based on a series of papers by Duane et al. published in the British Dental Journal to help dental practices implement more environmentally friendly measures. Module information was presented in short video format through PowerPoint slides and a voiceover. Sections 1 and 2 introduced students to the topic of environmental sustainability and its importance by highlighting climate change impacts sourced from human activities. Section 3, “Healthcare & Dentistry”, drew the connection between climate change and dentistry. For example, there was a section that explored the environmental dangers of using mercury-based material such as amalgam. “Sustainable Laws & Policies” informed study participants on the current state of policies and current administration regarding environmentally sustainable dentistry and healthcare. Finally, the “Applications” section was designed to inform students on the utilization of sustainable dentistry and introduced methods that they could employ in private practice to

minimize the environmental impact of a typical US based dental practice. Content based questions were embedded throughout the module to promote participant engagement and information retention. The embedded questions and responses were not recorded for the purposes of this study.

Post-Module Assignment

Three weeks following module completion, all second-year DH students were given a short assignment to enforce information taught in the module. Students were expected to identify an area of dentistry that may or may not benefit from a sustainable approach. They evaluated the pros and the cons of the approach, described any challenges towards implementing the change, and they also identified alternative sustainable products if applicable. For example, plastic toothbrushes could be replaced by bamboo toothbrushes. Learners reported their findings via VoiceThread, a collaborative online tool that allows users to present virtually with slides/images, on Sakai and were expected to comment on at least two of their classmate's presentations. Following the assignment, students were given the opportunity to provide further feedback on the assignment. Survey responses were, again, anonymous and students could indicate whether they opted in for their feedback to be utilized in the study.

Assignment Survey Instrument

The post-assignment survey (Appendix C) was administered over Qualtrics and pilot tested for face validity by dental hygienists who had graduated within three years. The pilot testers were asked to provide feedback on time to complete the survey, ease of readability, and question comprehension. The post-assignment survey was designed to take no more than 8 minutes to complete.

The same thirty-four second year DH students were recruited to participate in the post-

module assignment survey three weeks after phase one of the study was complete. While completion of the assignment was mandatory, participation in the survey and study was not. Post-assignment survey questions utilized a combination of Likert-style and open-ended questions to gauge student impressions toward the value of the post-module assignment. For example, question 2 asked, “This assignment helped me apply concepts learned in the module in the real world.” Likert-style response options ranged from “disagree” to “agree”.

Four qualitative questions in the assignment survey were organized into the following categories: enrichment, change, and continuity. These questions helped determine what the student thought should be discontinued, continued or added to improve their learning experience. For example, question 7 asked, “What part(s) of this assignment should be stopped/changed to improve the learner experience?”.

Statistical Analysis

Quantitative statistical analysis was completed using the software SAS 9.4 (SAS Institute Inc., Cary, NC). Paired t-tests were used to compare participant responses from pre- and post-surveys. Survey responses were grouped into the following subgroups: pre-knowledge, pre-attitude, post-knowledge, post-attitude, and self-perceived module effectiveness. All tests were conducted at the 95% confidence interval and significance was set at $p < 0.05$. Univariate and bivariate analyses were also performed.

Descriptive coding was used for open-ended responses. The codes were then categorized to create themes. Quotes, representative of these themes, were used to present the data. Analysis bias was minimized with validity testing of the responses and code book. Anonymous survey responses as well as the primary code book were sent to the validity tester. The secondary validity tester first analyzed the data themselves and created their own descriptive codes and

corresponding themes. The validity tester then utilized the code book presented by the primary investigator to analyze the data. Analysis and results were sent back to the primary investigator to determine interrater reliability.

Results

Out of the thirty-four students, twenty-five completed the pre- and post-surveys (Response Rate: 71.4%). Responses that were incomplete or lacked matching pre-/post-surveys were omitted from study analysis. Of these twenty-five responses, twenty-four had matching pre-/post-survey responses (RR: 68.6%). The pre-survey data revealed that 74% (n = 20) of students were supportive of implementing environmentally friendly dentistry. 89% (n = 24) self-reported possessing little to a moderate amount of knowledge on environmental sustainability and 33% (n = 9) felt that they possessed little to no knowledge at all on climate change. Figure 3 depicts a comparison of the initial attitudes and knowledge for each study participant.

Study participants scored an average of 1.987 out of 6 (standard deviation (SD) ± 0.651) possible points on knowledge in the pre-survey. In the post-survey, knowledge scores increased 0.9167 points to an average of 2.917 points out of 6 points (SD ± 0.496). Statistical analysis with a paired t-test showed that there was a statistically significant ($p < 0.0001$) positive difference between pre-survey knowledge scores and post-survey knowledge scores. Figure 4 displays the agreement trend of pre-knowledge scores and post-knowledge scores.

Study participants scored an average of 6.085 points out of 7 (SD ± 0.852) total possible points on attitude in the pre-survey. Attitude scores increased by 0.7083 points to an average of 6.744 points out of 7 (SD ± 0.541) total possible points in the post-survey. The paired t-test again showed that there was a statistically significant ($p<0.0001$) positive difference between pre-survey attitude scores and post-survey attitude scores. Figure 5 displays the agreement trend of

pre-attitude scores and post-attitude scores. The most significant area of change in DH attitudes was their belief on whether environmentally sustainable dentistry is achievable without compromising current standards of care. In the pre-survey, only 26% (n = 7) strongly agreed that environmentally sustainable dentistry did not compromise current standards of care. However, post-survey results revealed that 41% (n = 11) strongly agreed and even more participants had increased their results to a more positive stance.

Responses to free response questions in the immediate post-module survey aligned with two major themes: module format and module content. Study responses regarding module content revealed an unanimously positive response. One such response was “It was very informative and eye opener to help the environment as part of the dental professionals.” Responses pertaining to module format were balanced between a positive and critical response. One study respondent expressed appreciation for the format, “I really liked the short video format”. While another expressed dissatisfaction with the pacing of the module, “Talked way too fast to keep up while taking notes.”

In the follow-up assignment 3 weeks after the module and surveys closed, students presented on topics such as autoclavable patient napkins, biodegradable gloves, reusable glass syringes, bamboo charcoal floss, and high-technology dry vacuum for water conservation as seen in Figure 6. The students discussed the benefits and challenges to implementing these types of measures in dental practice. According to these projects, some of the most common challenges to implementing ESD were high startup costs. However, most students researched and found that the startup costs eventually pay for themselves over time and save more money compared to not implementing ESD measures.

Twenty-two students responded (RR: 64.7%) to the post-module assignment survey and

phase two of this study. According to the univariate analysis conducted, 100% of the study responses expressed that the reflective assignment was at least "somewhat helpful" and a valuable supplement to the module intervention. Additionally, 90% (n = 20) of study responses felt that the reflective assignment helped students to apply module concepts in the real world and 95% (n = 21) of the study respondents learned about a dental product that they previously were unaware of. Ninety percent (n = 20) of study respondents felt that the assignment helped them to at least somewhat think creatively and/or critically on environmental sustainability and dentistry. The composition of these responses can be found in Table 1.

Responses to the open-ended post-module assignment survey questions revealed the themes: reinforcement, critical thinking, behavioral change, satisfactory, external factors, design, content, and non-applicable. The responses to these themes and their descriptions can be found in Table 1. Most responses indicated that the follow- up assignment was useful in helping students apply concepts introduced in the module to the real world and in clinic. Additionally, 9% (n = 2) stated that the assignment pushed them to think critically on methods to reduce dental waste and conduct their own research. For example, one study participant said, "Continue to encourage independent research. I thought that was the most interesting part of the project, learning about all the efforts to make dentistry more sustainable." 18% (n = 4) expressed that the assignment was flawed due to external factors such as "This project came along in the same week when all of our (other) projects were due".

Discussion

ESD is not a popular topic in the US for a variety of reasons. Among these is a lack of awareness and knowledge on the extent of how US based dentistry affects the environment. More research needs to be done on the effect that dentistry has on the environment and how the

introduction of ESD into dental and dental hygiene education can influence dental environmental impact. There is also a need for more ESD educational material for both students and practicing clinicians. This study helped to fill in this gap of knowledge by implementing an educational intervention and assessing its effectiveness on DH student's perceptions of environmentally sustainable practices in dentistry. While the study intervention was planned to be an in-person seminar with active learning opportunities such as group discussions to enforce learner engagement and information retention. Due to the COVID-19 pandemic, students were unable to attend an in-person seminar and the intervention had to occur online. To minimize barriers for students to participate in the study, the module was also designed to be completed asynchronously and prioritized participant engagement. Module information was also presented in short video format with embedded questions to emphasize key points within the videos and account for lack of in person interactions. Each video was approximately 4 – 5 minutes long with minimal text, pictures, and figures.

The switch from an in-person seminar to an online educational intervention did not appear to affect the quality and effectiveness of education. According to study responses, module design was one of the major strengths of the intervention. Students indicated that they appreciated the module for its novel content and design featuring short video presentations with accompanying questions. Responses included "It was very informative and (an) eye opener to help the environment as part of (the) dental profession", and "I really liked the short video format". These findings support Allen, Mabry et al.'s evaluation of distance learning with meta-analysis as their results demonstrated no significant decline in effectiveness of online education.[13]

Experimental findings from all portions of the study refuted the null hypotheses;

practical, policy, and research implications were developed following evaluation of the study results.

Practical Implications

The multi-functional pre-module survey determined the effect of the asynchronous online educational module on student knowledge, attitudes, and receptiveness towards the module topic and established the baseline knowledge and attitudes that DH students possessed towards environmentally sustainable dentistry. Pre-survey data indicate that while DH students may be receptive to any future shifts towards environmentally friendly dentistry, they lack the knowledge and means to push for that change and advocate for it. These results correspond to Parchure et al.'s research on barriers to implementing ESD in dental education which include lack of knowledge and awareness on ESD.[12]

As Parchure et al. suggest, the shortage of educational material on ESD should be considered when determining the causes behind the absence of knowledge and awareness of ESD in dental and dental hygiene students.[12] As study participants scored statistically significantly higher on both knowledge and attitude in the immediate post-module survey, creating more ESD educational material like this study's online module may be helpful in disseminating ESD knowledge to students as well as towards implementing ESD in dental hygiene curricula. The educational materials created for the purpose of this study can be reproduced or serve as a model for future educational interventions related to ESD.

Implementation of a follow-up assignment following any educational interventions is also recommended. Based on post-assignment survey responses, most of the study participants felt that the follow-up assignment was beneficial to their learning about environmentally sustainable dentistry. In the post-assignment surveys, 86% (n = 19) of study participants indicated that the

assignment allowed them to better grasp the educational module material. When asked on how the assignment supported the educational module, responses included "(The assignment) provided real life examples, (and) gave ideas on how to reduce waste." Students also felt that the assignment pushed them to make behavioral changes in clinic to limit waste. One such response was, "I've tried to be less wasteful in clinic because of the environmental lesson."

Integrating environmental sustainability into the dental hygiene curriculum may also create opportunities for interprofessional education and collaboration. As previously discussed, the British Centre for Sustainable Healthcare (CSH) has a Fellows and Scholars program where healthcare professionals of various backgrounds learn about environmental sustainability and are trained on how to incorporate it into their practice.[8] A similar approach can be adopted here in the United States. Dental hygiene, dental, nursing, and other students of various healthcare backgrounds could learn together and identify areas of practice within their respective professions that would benefit from a sustainable approach. Not only would they be able to learn more from each other and about other healthcare fields, but the students would also learn from experts that they may not have a chance to hear from otherwise. These include environmentalists, scientists, and public health experts.

The feasibility of IPE on environmentally sustainable healthcare is especially promising in educational settings where there are already student groups dedicated to the topic. For example, there is great potential for IPE opportunities between medical, dental, dental hygiene, public health, nursing students etc.at UNC-Chapel Hill due to the recent founding of CLEAN at UNC-Chapel Hill School of Medicine.[14]

Research Implications

Although the educational module intervention supported the study hypothesis that the

study intervention would be effective in improving DH student knowledge, attitudes and perceptions towards environmentally sustainable dentistry, there were areas of weakness that should be addressed in future research.

One of the limitations of the study was participant recruitment and response rate. Due to the COVID-19 pandemic situation, opportunities to recruit study participants and all parts of the study had to occur virtually. Recruitment and data gathering also occurred during the beginning of the COVID pandemic where study participants found themselves in volatile and likely overwhelming situations. This posed as a challenge in reaching out to potential study participants outside of the UNC-CH ASoD second-year DH class. Furthermore, as mentioned before, quick changes were necessary and negatively affected the timing of the follow-up assignment. Many of the DH students felt that the announcement for the assignment should be given earlier, presumably with the module.

Further studies and any implementation of environmentally sustainable dentistry curriculum material should take this into consideration and provide students with all the aspects of the learning experience early on or inform them ahead of time. It would also be beneficial to employ a mix of in-person and virtual recruitment techniques to students from multiple schools in different areas to account for regional differences in beliefs on climate change and environmental sustainability. For example, NC is restrictive in its allowances for DH practices (i.e., dental hygienists are not permitted to provide local anesthesia). These restrictions may be a confounding variable in DH student attitudes and receptiveness on the importance of environmentally friendly dentistry. DH students in states with expanded DH functions may feel that they can more of a difference in ESD compared to DH students in constrictive states.

DDS students should be surveyed as well to gauge their levels of knowledge and

receptiveness on practicing environmentally sustainable dentistry. While there were initial efforts to recruit 3rd/4th year DDS students at the ASoD, the response rate was minimal and recruitment of and responses from DDS students were disregarded. It would also be prudent to consider including dental and dental hygiene faculty in future studies. This would provide a more comprehensive understanding of the opportunities and challenges to implementing ESD in dental and dental hygiene curricula.

Finally, while the quality of education did not diminish, future research may also consider implementing alternative types of educational interventions that incorporate more face-to-face interactions. Comparisons between live, virtual only, and hybrid educational interventions could also be compared to determine which educational delivery method may be the most effective.

Policy Implications

Introduction of environmental sustainability into the dental hygiene curriculum should be considered a strength as minimizing dental waste and its environmental impacts are closely tied in to patient and public health. The results of this study and others like it can be to advocate for the widespread implementation of ESD in dental hygiene instruction. In this study, the majority of the students were receptive towards the material, learned about new and alternative products, and found the learning experience to be fulfilling. The change introduced by integrating ESD into dental hygiene education may be a catalyst in standardizing ESD in US based dental practices.

Incorporation of ESD also encourages students to think outside of the box and consider how their practices as clinicians may have long lasting effects beyond the immediate confines of the dental office. This educational topic allows for more IPE opportunities and can be used to

advocate for the importance and standardization of IPE in education.

Concluding Comments

This pilot study on the feasibility and receptiveness of dental hygiene students on incorporating environmental sustainability into US-based dental hygiene education achieved the study objective and goals. The educational module created for this study can further be used as a model for future educational interventions on educating dental hygiene students on environmentally sustainable dental practices. By beginning the intervention of raising awareness and instruction on environmental sustainability during the educational phase for future dental hygienists and other healthcare providers, there may be more success in standardizing and widespread implementation of the practice of environmentally sustainable dentistry and healthcare.

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Table 1. Themes and Corresponding Description and Composition for Qualitative Data of Post-Module Assignment Survey

Code	Description	Frequency	Example(s)
Reinforcement	Statements that follow-up assignment helped them further their understanding of material taught in module/filled in the gaps.	6	"I learned about how we use a lot of stuff that has a better alternative." "It opened my eyes to the amount of waste that comes from practicing dentistry."
Critical Thinking	Includes information that follow-up assignment helped them to apply critical thinking and go a step beyond what the module taught.	3	"...gave ideas on how to reduce waste." "I thought that (doing independent research) was the most interesting part of the project, learning about all the efforts to make dentistry more sustainable."
Behavioral Change	Student states or alludes that follow-up assignment pushed them to change their behavior regarding waste. This includes considering their own contributions to environmental waste. One student discussed possible barriers to doing this in dentistry due to infection control procedures.	2	"I've tried to be less wasteful in clinic because of the environmental lesson." "Allowed me to think about how to contribute to a more sustainable environment."
Satisfactory	Student states or alludes that follow-up assignment was satisfactory as it was.	8	"Lesson is great as is!" "The videos were helpful and served as a memorable way to express content". "Continue breakdown of material, well organized and easy to understand." "Short videos that are concise and easy to follow."
External Factors	Student states or alludes that follow-up assignment was less than satisfactory due to external factors such as exams or other assignments due.	4	"Don't wait until almost final weeks to ask us to do the project." "For the project to given a week before finals begin or if it was announced earlier when we started the unit we could have knocked it out as

			opposed to getting stress with it being due the same time at other class projects and finals."
Design	Student states or alludes that follow-up assignment can be improved with changes in the assignment design.	2	"Printable/downloadable version for notes/reference." "When engaging in the content and clicking through each section, it's easily to miss questions. Therefore, would prefer them all in one place."
Content	Student states or alludes that follow-up assignment can be improved with changes to the assignment content.	3	"More examples on how to cut down unnecessary waste." "More information on how the dental office can reduce carbon footprint and alternatives to materials and barriers."
Non-applicable	Student does not provide an answer that is relevant to the question.	1	"I felt that the options for environmental sustainability in a dental office given were not realistic for keeping up with infection control. I felt that even if we wanted to create a more environmentally conscious office, we would be sacrificing something."

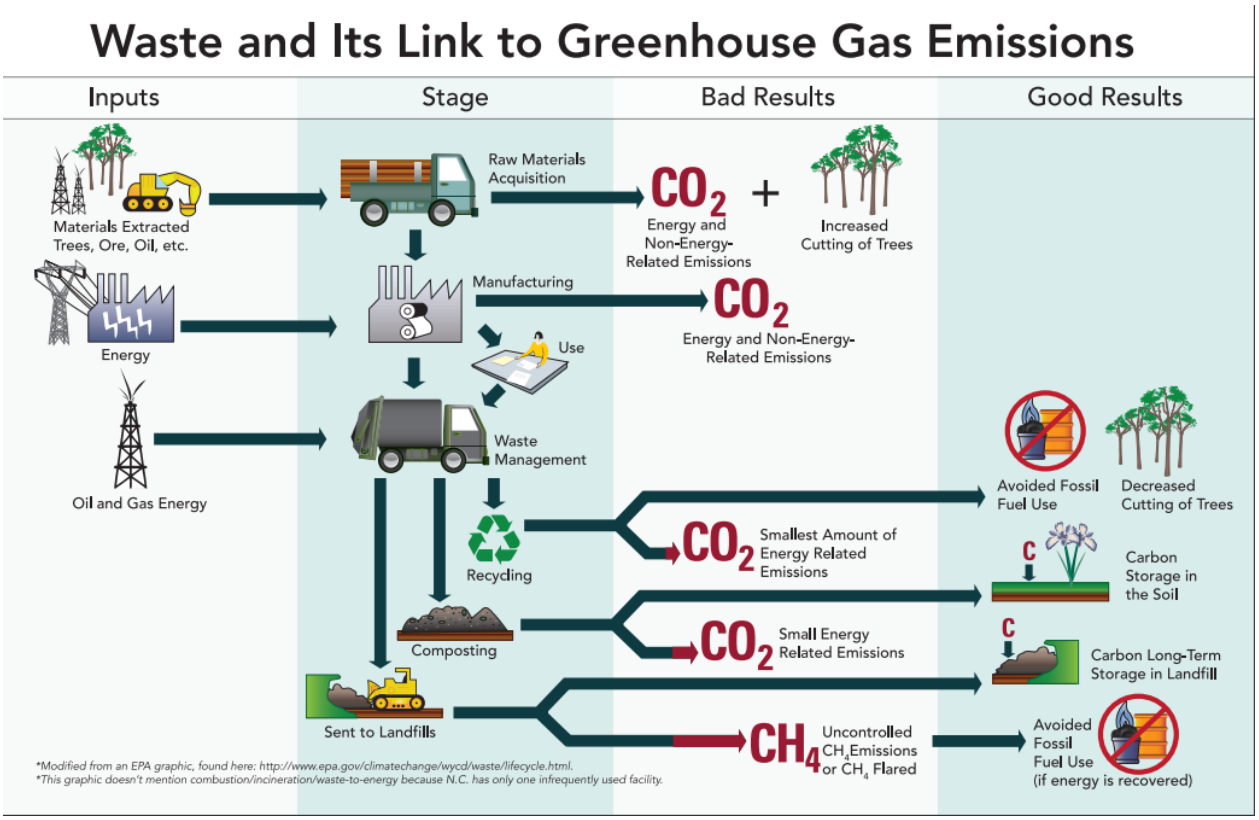

Figure 1. Waste and Its Link to Greenhouse Gas Emissions

The figure above depicts the relationship between procurement, consumption and disposal of goods and the environment. Greenhouse gases and waste are emitted at every step and should be considered when evaluating one's environmental impact.

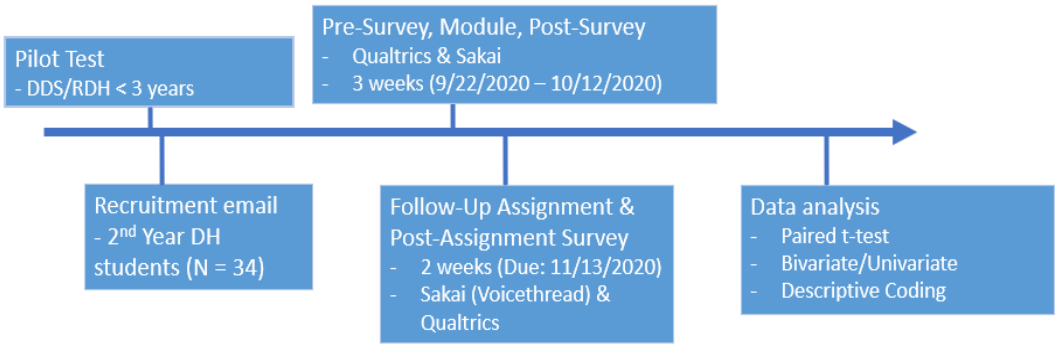

Figure 2. Study Design and Flow

The figure above depicts the flow of study design from pilot testing to data analysis.

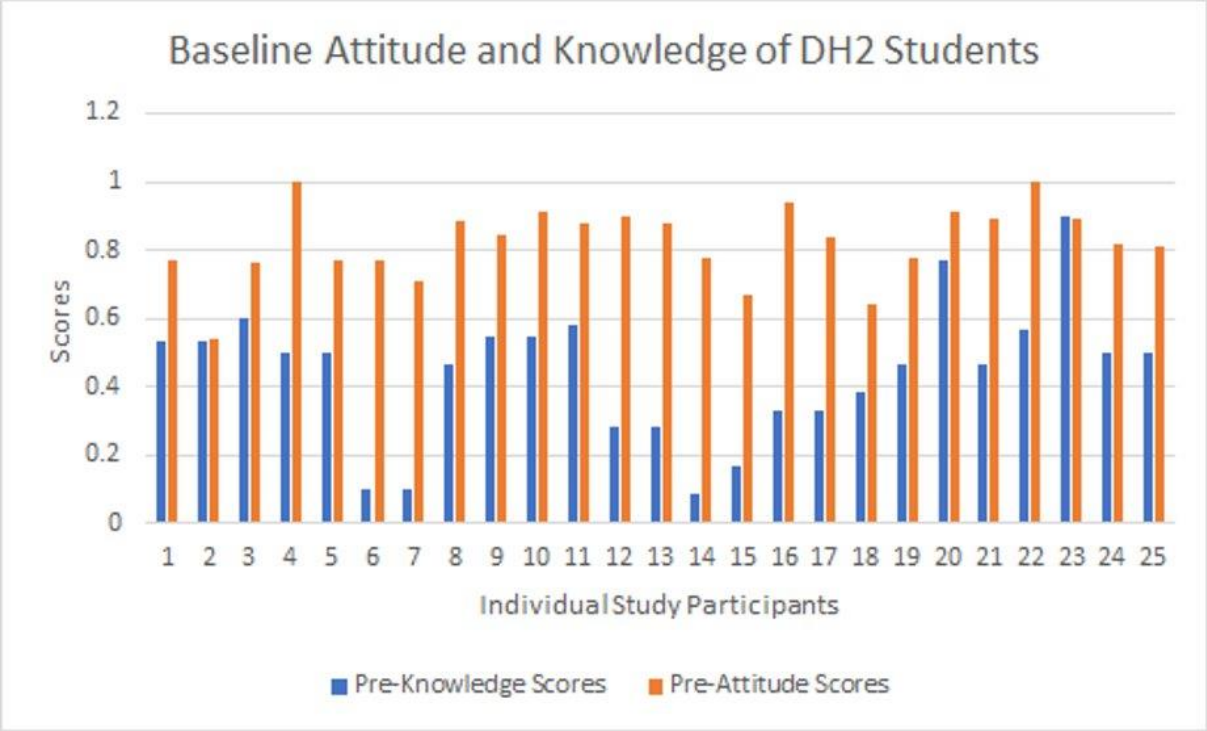

Figure 3. Baseline Attitude and Knowledge of DH 2 Students

This figure displays a side-by-side comparison of individual knowledge (blue) and attitude (orange) pre-survey scores for each study participant. Bivariate analysis of these results determined that while DH students were receptive towards ESD, their level of knowledge was comparatively lacking.

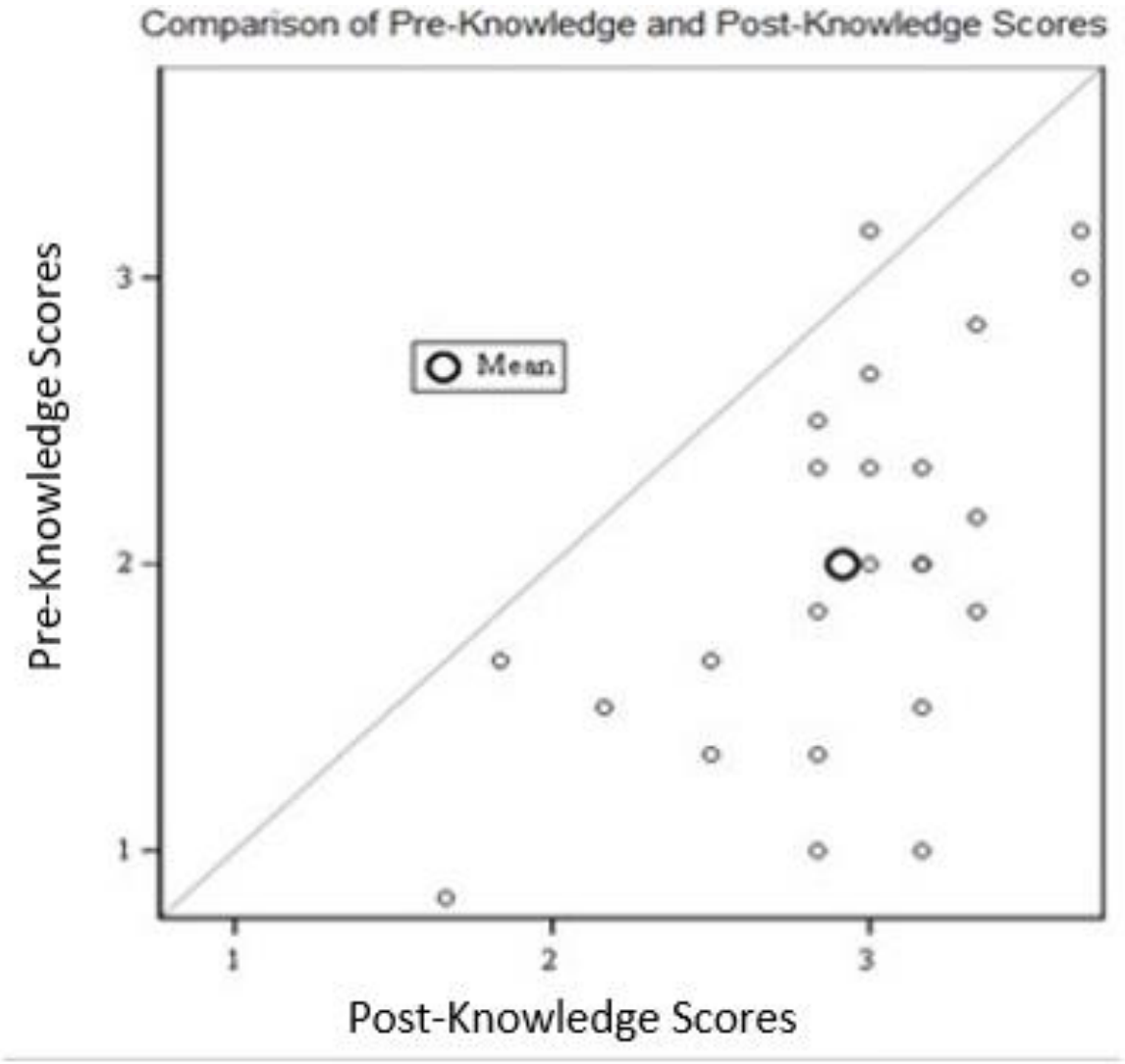

Figure 4. Agreement between Pre-Knowledge and Post-Knowledge Scores after Completion of Study Module

This figure displays the positive agreement trend between pre-knowledge and post-knowledge scores on environmental sustainability and climate change of study participants after completing the educational online module. The scores display an upwards/positive trend, indicating that knowledge scores for study participants consistently increased following module completion.

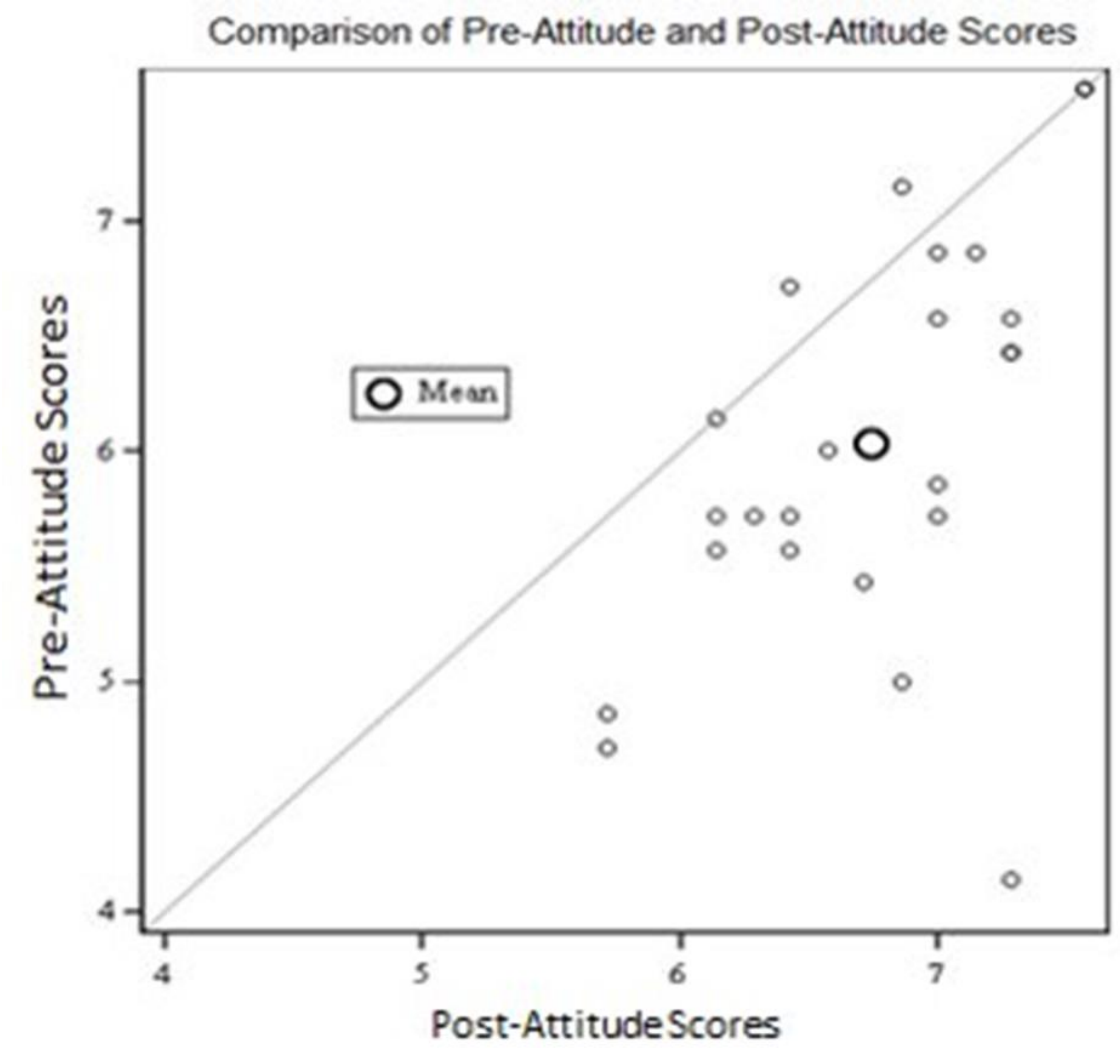

Figure 5. Agreement Between Pre-Attitude and Post-Attitude Scores after Completion of Study Module

This figure displays the agreement trend between pre-attitude and post-attitude scores on environmental sustainability and climate change from study participants after completing the educational online module. The scores display an upwards/positive trend, indicating that attitude scores for study participants consistently increased following module completion.

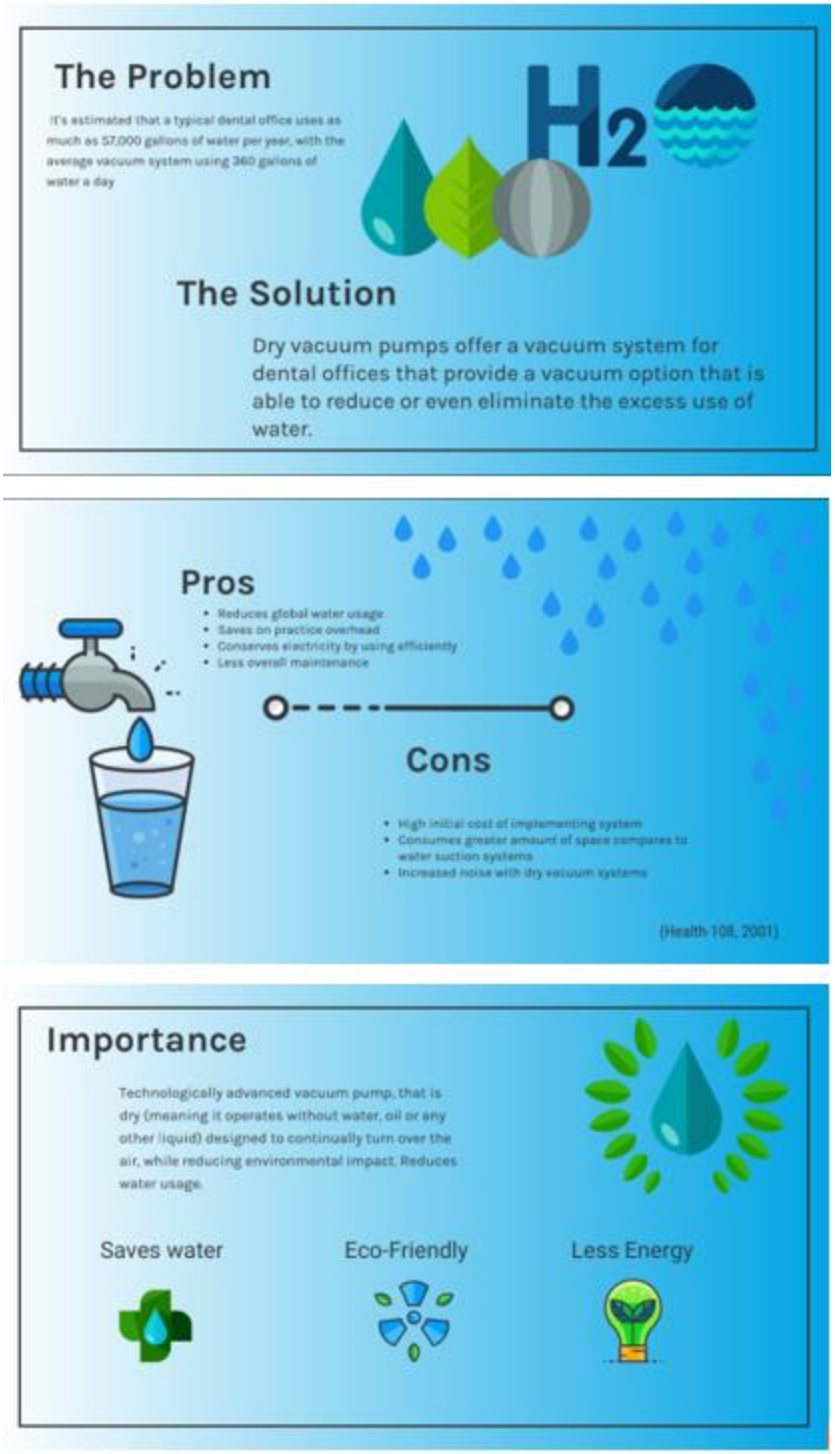

Figure 6. Sample of Student Project on High-Technology Dry Vacuum for Water Conservation

The figure above displays part of a student project on water consumption of dental offices. They researched and presented on an alternative water vacuum system that would reduce excess use of water. They highlighted the positives, negatives and challenges to implementation of this new system as well.

APPENDIX A: PRE-SURVEY

This is your random ID number, please record in the box below. You will also need this number for your post-survey, please have it recorded somewhere accessible for you as well. ${e://Field/Random%20ID}

Which of the following applies to you for the 2020-2021 academic school year?

- ○ DDS 3rd year
- ○ DDS 4th year
- ○ DHYG 2nd year

Please select the level of knowledge that you possess on climate change. (1 = no knowledge, 5 = neutral, 10 = very knowledgeable)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Please select the level of knowledge that you possess on environmental sustainability. (1 = no knowledge, 5 = neutral, 10 = very knowledgable)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Please select the level of impact that you believe dentistry has on the environment. (1 = no impact, 5 = moderately impactful, 10 = extremely impactful)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Please select how applicable environmental sustainability is to dentistry and vice versa. (1 = no applicability, 5 = moderately applicable, 10 = extremely applicable)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Which of the following is not a major greenhouse gas?

- ○ Nitrous Oxide
- ○ Carbon Dioxide
- ○ Methane
- ○ Hydrogen

Which of the following manufacturers/suppliers offer recycling options at UNC-Chapel Hill? (select all that apply)

- ☐ Kimberly Clark
- ☐ Johnson & Johnson
- ☐ VWR
- ☐ Fischer Scientific

The ocean acts as a (_____) for the planet by absorbing greenhouse gases and heat from the atmosphere.

- ○ Newton regulator
- ○ Thermal sponge
- ○ Heat sink
- ○ Heat reflector

Which of the following global treaty/agreement targets the reduction of mercury & amalgam use?

- ○ Paris Agreement
- ○ Minamata Convention

- ○ Kyoto Summit
- ○ Clean Air Act

Please indicate your level of agreement with this statement: Environmental sustainability is important.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Please indicate your level of agreement with this statement: Environmentally sustainable dental practices are important.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Please indicate your level of agreement with this statement: US dental practices have an ethical obligation to transition to more environmentally sustainable practices.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Please indicate your level of agreement with this statement: Environmentally sustainable dentistry is achievable without compromising current standards of care.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Upon entering the workforce, I would be (...) of practicing environmentally sustainable dentistry.

Supportive	Slightly supportive	Indifferent	Slightly against	Against
○	○	○	○	○

Reminder: Please remember to record your ID number, it will be needed in your post-survey. You may press the back button below to go back to the beginning of the survey where your ID number is. Otherwise, you may now continue to the online module.

APPENDIX B: POST-SURVEY

Please record below the random ID number that you were given in the pre-survey.

Please select the level of knowledge that you possess on climate change. (1 = no knowledge, 5 = neutral, 10 = very knowledgeable)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Please select the level of knowledge that you possess on environmental sustainability. (1 = no knowledge, 5 = neutral, 10 = very knowledgable)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Please select the level of impact that you believe dentistry has on the environment. (1 = no impact, 5 = moderately impactful, 10 = extremely impactful)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Please select how applicable environmental sustainability is to dentistry and vice versa. (1 = not applicable, 5 = moderately applicable, 10 = extremely applicable)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Which of the following is not a major greenhouse gas?

- ○ Nitrous Oxide
- ○ Carbon Dioxide
- ○ Methane
- ○ Hydrogen

Which of the following manufacturers/suppliers offer recycling options at UNC-Chapel Hill? (SELECT ALL THAT APPLY)

- [ ] Kimberly Clark
- [ ] Johnson & Johnson
- [ ] VWR
- [ ] Fischer Scientific

The ocean acts as a (_____) for the planet by absorbing greenhouse gases and heat from the atmosphere.

- ○ Newton regulator
- ○ Thermal sponge
- ○ Heat sink
- ○ Heat reflector

Which of the following global treaty/agreement targets the reduction of mercury & amalgam use?

- ○ Paris Agreement
- ○ Minamata Convention
- ○ Kyoto Summit
- ○ Clean Air Act

Please indicate your level of agreement with this statement: Environmental sustainability is important

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Please indicate your level of agreement with this statement: Environmentally sustainable dental practice is important

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Please indicate your level of agreement with this statement: US dental practices have an ethical obligation to transition to more environmentally sustainable practices.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Please indicate your level of agreement with this statement: Environmentally sustainable dentistry is achievable without compromising current standards of care.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
○	○	○	○	○	○	○

Upon entering the workforce, I would be (...) of practicing environmentally sustainable dentistry.

Supportive	Somewhat supportive	Indifferent	Somewhat against	Against
○	○	○	○	○

Please select the appropriate response: This online module increased my knowledge on environmentally sustainable dentistry...

- ○ A great deal
- ○ Somewhat
- ○ A little
- ○ Not at all

Please select the appropriate response: This online module increased my interest in learning more about environmentally sustainability dentistry.

- ○ A great deal
- ○ Somewhat
- ○ A little
- ○ Not at all

If you have any further feedback regarding this module and your experience with it, please let us know down below.

If you would like to be eligible for a chance to win a $15 Amazon giftcard, please fill out your name and email that you would like to receive the giftcard. (ex. John Doe, johndoe@email.com) The giftcard will be emailed out to the winners after the data collection period. Otherwise, please press next and the survey will be completed.

APPENDIX C: POST-ASSIGNMENT SURVEY

Thank you for providing feedback for this assignment. Please fill out the survey to completion and indicate your consent at the end.

This assignment helped me apply concepts learned in the module in the real world.

Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
○	○	○	○	○

This assignment helped me learn about environmental sustainability and dentistry.

Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
○	○	○	○	○

I learned about a sustainable dental product that I was not aware of/had little knowledge of before.

Yes	No
○	○

This assignment helped me think creatively and/or critically on environmental sustainability and dentistry.

Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
○	○	○	○	○

If applicable, how did this assignment enrich your learning experience?

What part(s) of this assignment should be stopped/changed to improve the learner experience?

What should added in this assignment to provide optimal learner experience?

What should be continued in this assignment to provide optimal learner experience?

I consent to have my survey responses be used in Ms. Leung's study. I understand that my survey responses are anonymous and will not have an impact on my grade or academic standing.

- [ ] Yes
- [ ] No