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Health professions education at a time of triple planetary crises

Edited by
Lynn Valerie Monrouxe, Jacqueline G. Bloomfield, Michelle McLean and Komal Atta

Coordinated by
Fathima Rizka Ihsan

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Health professions education at a time of triple planetary crises

Topic editors
Lynn Valerie Monrouxe — The University of Sydney, Australia
Jacqueline G. Bloomfield — The University of Sydney, Australia
Michelle McLean — Bond University, Australia
Komal Atta — University Medical and Dental College, University of Faisalabad, Pakistan

Topic coordinator
Fathima Rizka Ihsan — The University of Sydney, Australia

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Table of contents

05 Editorial: Health professions education at a time of triple planetary crises
Komal Atta, Fathima Rizka Ihsan, Jacqueline G. Bloomfield, Lynn V. Monrouxe and Michelle McLean

08 Perspectives on climate action and the changing burden of infectious diseases among young Italian doctors and students: a national survey
Francesco Vladimiro Segala, Francesco Di Gennaro, Lucia A. A. Giannini, Giacomo Stroffolini, Agnese Colpani, Andrea De Vito, Stefano Di Gregorio, Luisa Frallonardo, Giacomo Guido, Roberta Novara, Angela Amendolara, Ilenia Annunziata Ritacco, Francesca Ferrante, Lorenzo Masini, Ilaria Iannetti, Salvatore Mazzeo, Silvia Marello, Nicola Veronese, Federico Gobbi, Roberta Iatta and Annalisa Saracino

16 Bridging disciplines-key to success when implementing planetary health in medical training curricula
Ebba Malmqvist and Anna Oudin

22 Climate change and its impact on health: a global collaborative learning model
Harriet Okatch, Patricia A. Remshifski, Anita Fennessey, Haley Campbell, Sivia Barnoy, Jason Friedman, Stephen B. Kern, Rosemary Frasso, Cecilia Sorensen, Tami Bar-Shalita and Louis N. Hunter

31 Planetary health literacy as an educational goal contributing to healthy living on a healthy planet
Carmen Jochem, Julia von Sommoggy, Anna-Katharina Hornidge, Eva-Maria Schwienhorst-Stich and Christian Apfelbacher

34 Development of a suite of short planetary health learning resources by students for students as future health professionals
Catarina Pais Rodrigues, Evangelos Papageorgiou and Michelle McLean

42 Triple planetary crisis: why healthcare professionals should care
Fathima Rizka Ihsan, Jacqueline G. Bloomfield and Lynn V. Monrouxe

48 Integrating planetary health education into tertiary curricula: a practical toolbox for implementation
Zerina Lokmic-Tomkins, Liza Barbour, Jessica LeClair, Jeneile Luebke, Sarah L. McGuinness, Vijay S. Limaye, Parvathy Pillai, Maxfield Flynn, Michael A. Kamp, Karin Leder and Jonathan A. Patz

61 Planetary health education in undergraduate medical education in Germany: results from structured interviews and an online survey within the national PlanetMedEd Project
Fabio Grieco, Sandra Parisi, Anne Simmenroth, Michael Eichinger, Janina Zirkel, Sarah König, Jana Jünger, Eva Geck and Eva-Maria Schwienhorst-Stich

73 Pedagogical strategies for supporting learning and student well-being in environmentally sustainable healthcare
Nara Jones, Graeme Horton, Michelle Guppy, Georgia Brown and John Boulton

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EDITED AND REVIEWED BY
Immanuel Azaad Moonesar,
Mohammed Bin Rashid School of Government, United Arab Emirates

*CORRESPONDENCE
Komal Atta
komal.atta@tuf.edu.pk

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Editorial: Health professions education at a time of triple planetary crises

Komal Atta[1]*, Fathima Rizka Ihsan[2], Jacqueline G. Bloomfield[3], Lynn V. Monrouxe[2] and Michelle McLean[4]

[1]Department of Medical Education, University Medical and Dental College, The University of Faisalabad, Faisalabad, Pakistan, [2]Faculty of Medicine and Health, Sydney School of Health Sciences, The University of Sydney, Camperdown, NSW, Australia, [3]Faculty of Medicine and Health, Sydney Nursing School, The University of Sydney, Camperdown, NSW, Australia, [4]Faculty of Health Sciences & Medicine, Bond University, Gold Coast, QLD, Australia

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Editorial on the Research Topic
Health professions education at a time of triple planetary crises

This Research Topic, "*Health professions education at a time of triple planetary crises*," includes nine articles that explore various dimensions of how health professions education must respond to the interrelated crises of a changing climate, biodiversity loss, and pollution. Collectively referred to as a "Triple Planetary Crisis," this phrase is no longer metaphorical. In late 2023, editors of more than 200 health journals urged the World Health Organization (WHO) to declare this interconnected climate-nature crisis a global health emergency, warning that it meets all the criteria for severity, international impact, and urgency of action (1). Separating the climate and nature (biodiversity loss and pollution) crises has led to fragmented responses and missed opportunities in terms of synergistic solutions. It is important to understand that the Planetary Health crisis encompasses climate change, biodiversity loss and pollution and needs to be addressed urgently. Subsequently, the development of eco-ethical leadership for dealing with planetary changes is an imperative in healthcare professions education (2).

The articles in this Research Topic weave together three interconnected threads that form the fabric of Planetary Health education: professional involvement, curriculum development, and student agency. Each theme strengthens and supports the others, creating a robust framework for transformative learning.

Professional involvement develops as healthcare practitioners confront their expanding role in addressing environmental challenges. The evolving perspectives of young doctors on climate-related issues (Segala et al.) illuminate this professional awakening, while the cultivation of Planetary Health literacy (Okatch et al.) equips practitioners with essential knowledge. Most urgently, the recognition that health professionals must address the triple planetary catastrophe (1) positions the medical community as active agents of change rather than passive observers.

Curriculum development serves as the structural foundation, providing the educational architecture needed to embed these critical concepts into formal learning pathways. This systematic integration ensures that Planetary Health education moves beyond *ad hoc* initiatives to become a core component of professional training (Pais Rodrigues et al.).

Student agency acts as the dynamic catalyst that brings theory into practice. Through the co-creation of learning resources (Pais Rodrigues et al.), students evolve from passive recipients to active architects of their education. This empowerment extends to learner-driven innovation, which is supported by the implementation of school kits (Lokmic-Tomkins et al.) and enriched by interdisciplinary approaches (Grieco et al.). Recognizing that engagement requires emotional and intellectual support, techniques for promoting student wellbeing help learners navigate the anxiety that can accompany confronting planetary-scale challenges (Malmqvist and Oudin).

Together, these three themes create a synergistic approach in which professional responsibility drives curricular innovation, student agency shapes meaningful learning experiences, and curriculum development provides the framework for sustainable change. Indeed, healthcare professionals have historically played a vital role in advocating for public health issues and they must now extend this advocacy to the triple planetary crisis, especially considering the health sector's own environmental footprint (Malmqvist and Oudin). Policymakers and educators must create a well-rounded, trickle-down policy on Planetary Health literacy, which includes educating the public. Underlying the scholarly contributions in this Research Topic is a foundational recognition—the triple planetary crisis is a health crisis. These articles highlight that including Planetary Health is not an optional extra in health professions education. It is a necessity to prepare knowledgeable health professionals who are skilled to take action to address our climate-nature crisis.

First, while there is consensus on the necessity, even the ethical obligation, of integrating Planetary Health into the education of healthcare professionals (Lokmic-Tomkins et al.) to prepare graduates to address the direct and indirect impacts of environmental degradation, implementation gaps persist. To this end, for Grieco et al., although the majority of German medical schools offer Planetary Health content, it is mainly electives, with little "core" curriculum. Segala et al.'s research found that although young Italian doctors and medical students exhibit substantial climate anxiety and are willing to act, their formal education about climate-health connections remains minimal. Similarly, while not a part of this Research Topic, studies in the Arab and Asian contexts show that despite awareness of the health threats of the triple crisis, policies and programs for action are scarce (3). Collectively, these studies suggest that while awareness is growing, the systematic, mandatory integration of Planetary Health into curricula remains elusive.

Secondly, as argued by Malmqvist and Oudin, integrating Planetary Health into medical education requires a transdisciplinary approach, involving expertise beyond traditional clinical sciences (Malmqvist and Oudin). Okatch et al. echoed this sentiment in their collaborative model in which faculty and students from diverse health professions and institutions co-developed courses on climate and health. These models illustrate how interdisciplinary education can enrich learning, foster broader systems thinking, and prepare health professionals for the complexity of environmental health challenges (Okatch et al.). Student leadership and innovation have also been identified as powerful forces for changing curricula. Pais Rodrigues et al. described a suite of 14 modular learning resources co-created by students and educators, offering flexible, accessible content grounded in authentic, learner-centered principles. This initiative demonstrates that students are not merely passive recipients of knowledge but critical agents in shaping educational responses to our Planetary Health challenges (Pais Rodrigues et al.).

The psychological burden of experiencing the triple planetary crisis must, however, be acknowledged. The studies included in this Research Topic also focus on the emotional dimensions of Planetary Health education, highlighting that, along with learner wellbeing, which must be supported through educational approaches that foster autonomy, relatedness, and competence (Pais Rodrigues et al.; Lokmic-Tomkins et al.; Grieco et al.), the emotional impact of the crisis on the population with which healthcare professional workers will be dealing must be realized. If these reforms are not included in curricula, there is a risk of disengagement.

Together, these articles invite broader debate and reflection on the evolving identity of health professionals. Healthcare professionals can no longer just be regarded as caregivers but also as advocates for a healthy planet (Pais Rodrigues et al.; Lokmic-Tomkins et al.; Ihsan et al.). The evolution of healthcare professionals' traditional roles from clinical caregiving to caring for the planet needs to be recognized and ecological consciousness, sustainability and advocacy must be integrated into professional identities (Grieco et al.; Malmqvist and Oudin; Jochem et al.).

As we delve deeper in the works in this Research Topic, questions arise that serve as food for thought for institutions and healthcare professional educators. First, how do we "center" Planetary Health education into HPE? Second, what policies and structures are needed to promote interdisciplinary collaboration across institutions, governments and the public? Third, how can we present "Planetary Health" as not just informing but inspiring awareness and health reforms in the face of overwhelming climate change, biodiversity loss and pollution?

In conclusion, this Research Topic presents a substantive and timely compilation of scholarly work examining how healthcare professions' education has evolved in response to the triple planetary crisis. The theoretical frameworks and empirical findings provide significant intellectual momentum for the advancement of Planetary Health education paradigms. These contributions collectively articulate the imperative of preparing healthcare professionals who are not only clinically competent but also have the requisite knowledge and advocacy skills necessary to address the complex interconnections between human health and ecological systems. The interdisciplinary perspectives offered in these articles establish a foundation for curricular transformation that acknowledges the inextricable relationship between planetary boundaries and health outcomes, thereby enriching both pedagogical approaches and professional identity formation in contemporary healthcare professions' education.

Author contributions

KA: Writing – original draft, Writing – review & editing. FI: Writing – review & editing. JB: Writing – review & editing. LM: Supervision, Methodology, Writing – review & editing, Conceptualization. MM: Writing – review & editing.

Conflict of interest

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EDITED BY
Jacqueline G. Bloomfield,
The University of Sydney, Australia

REVIEWED BY
Jamie Harvie,
Psychedelic Research and Training Institute, United States
Ioannis Sebos,
National Technical University of Athens, Greece
Yohan Robinson,
University of Gothenburg, Sweden

*CORRESPONDENCE
Francesco Vladimiro Segala
✉ fvsegala@gmail.com

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Perspectives on climate action and the changing burden of infectious diseases among young Italian doctors and students: a national survey

Francesco Vladimiro Segala[1,2]*, Francesco Di Gennaro[1], Lucia A. A. Giannini[2], Giacomo Stroffolini[2,3], Agnese Colpani[4], Andrea De Vito[4,5], Stefano Di Gregorio[1], Luisa Frallonardo[1], Giacomo Guido[1], Roberta Novara[1], Angela Amendolara[1], Ilenia Annunziata Ritacco[1], Francesca Ferrante[1], Lorenzo Masini[6], Ilaria Iannetti[2], Salvatore Mazzeo[2], Silvia Marello[2], Nicola Veronese[7], Federico Gobbi[3], Roberta Iatta[8] and Annalisa Saracino[1]

[1]Clinic of Infectious Diseases, Department of Precision and Regenerative Medicine and Ionian Area (DiMePRe-J), University of Bari "Aldo Moro", Bari, Italy, [2]Doctors4Future, "Chi si Cura di Te?", Rome, Italy, [3]Department of Infectious-Tropical Diseases and Microbiology, IRCCS Sacro Cuore Don Calabria Hospital Negrar, Verona, Italy, [4]Unit of Infectious Diseases, Department of Medicine, Surgery, and Pharmacy, University of Sassari, Sassari, Italy, [5]PhD School in Biomedical Science, Biomedical Science Department, University of Sassari, Sassari, Italy, [6]Scientist Rebellion, Verona, Italy, [7]Geriatric Unit, Department of Medicine, University of Palermo, Palermo, Italy, [8]Interdisciplinary Department of Medicine, University of Bari, Bari, Italy

Background: The eco-climatic crisis has been defined by the World Health Organization as the "single biggest health threat facing humanity," influencing both the emergence of zoonoses and the spread of vector-borne and water-borne diseases. The aim of this survey was to explore knowledge, eco-anxiety and attitudes toward the ecological and climate crisis among young Italian doctors and medical students.

Methods: A cross-sectional, multicenter survey was conducted from November 2022 to June 2023, by administering an anonymous questionnaire to Italian doctors and students of medicine. Endpoint of the study was a Knowledge, Attitudes and Practices (KAP) score on ecological and climate crisis (0–20 points). Association between variables and KAP score was assessed by Kruskal-Wallis' or Spearman's test, as appropriate, and significant variables were included into ordinal regression model and reported as adjusted odds ratio (aOR) with their 95% confidence intervals (CI).

Results: Both KAP and eco-anxiety scores showed acceptable levels of consistency with Cronbach's alpha. A total of 605 medical doctors and students living in 19 Italian regions were included in the study. Median age [Q1-Q3] was 27.6 [24.1–31.3] and females were 352 (58.2%). Despite showing good attitudes toward climate action, knowledge gap were found, with 42.5% (n = 257) of the respondents not knowing the temperature limits set by the Paris Agreements and 45.5% (n = 275) believing that climate change is caused by sunspots. Fears suggestive for eco-anxiety were common. At multivariable ordinal regression, high levels of eco-anxiety (aOR 1.29, p = 0.001) and low trust in government

action (aOR 1.96, $p = 0.003$) were associated with a higher KAP score. Only one Italian medical school offered an educational module on climate change.

Conclusion: Young Italian doctors and medical students are concerned about the climate crisis but show poor knowledge of these topics. The Italian academic system should urgently respond to this need.

KEYWORDS

medical education, climate change, planetary health, infectious diseases, eco-anxiety, climate action

1 Introduction

Climate change is a global health emergency. Human activities are leading to a dramatic increase in global terrestrial and marine temperatures resulting in food and water insecurity, sea-level rise and intensification of extreme weather events such as storms, heatwaves, wildfires, drought, floods and cyclones (1). This has the potential to trigger multiple tipping points that would set climate dynamics out of control (2). In addition, uncontrolled urbanization, deforestation and land-use change have caused the disruption of many of the earth's ecosystems, contributing to drive the ongoing sixth mass extinction event (3, 4) and an upsurge of zoonosis and other infectious diseases (5, 6).

The health impact of the climate crisis is multifactorial and profound. The World Health Organization (WHO) has estimated that, between 2030 and 2050, 250′000 people per year are expected to die as a consequence of climate change-driven malnutrition, malaria, diarrhea and heat alone (7). Also, air pollution is one of the highest risk factors for respiratory and cardiovascular diseases (8), and heatwaves cause every year more morbidity and deaths, especially among the most fragile (9). Extreme climatic events are causing victims both directly and indirectly—due to greater poverty, food insecurity and infectious diseases' outbreaks—while driving half of world internal displacements in 2022 (10). Mental health disorders related to climate events, such as ecoanxiety and solastalgia, are increasingly common (11). Since human health is deeply affected by both the climate and nature crisis, for the purpose of this work we adopted the umbrella term of "eco-climate crisis."

Despite a widespread lack of climate-sensitive medical education, clinicians worldwide are already facing the impacts of climate change on human health (12). With a dedicated working group for Planetary Health education, the European Planetary Health Hub has aimed to integrate Planetary Health education at all levels, including the future generation of doctors (13). Several countries, such as Germany, the Netherlands and the United Kingdom, have started to implement Planetary Health courses in their medical school curricula (14–16). In contrast, in other countries such as Italy, an ecologically sensitive medical education is still lacking, likely limiting physicians' ability to identify and address climate change-related issues in their clinical practice.

As a first step to understand the need for Planetary Health education in the Italian medical school curricula, we performed a survey on the impacts of eco-climatic crisis on human health. Aim of this study is therefore to explore knowledge about the eco-climate crisis, attitudes and practices toward climate action and feelings of eco-anxiety among young Italian doctors and medical students.

2 Materials and methods

2.1 Study design and population

We conducted a cross-sectional, multicenter survey from November 2022 to June 2023, by administering an anonymous structured questionnaire. Target population for the survey were Italian medical students, medical residents and doctors. Different typologies of postgraduate medical specialties were classified into clinical, non-clinical and surgical areas as for the Italian Ministry of University and Research classification (DM 68/2015). Italian regions were categorized into Northern, Central, and Southern Italy following the classification system utilized by the Italian National Institute of Statistics (17).

Study population was recruited by convenience sampling. To minimize selection bias, we adopted a multicenter design with a broad geographical setting (19 regions) and we conducted a multivariate analysis accounting for potential confounders. Given the descriptive purposes of the study, no *a-priori* sample size estimation was conducted. Written informed consent was obtained prior to survey administration. To understand to which extent Italian medical schools were addressing the issue of climate crisis impact on human health, publicly available curricula of all Italian Medical Universities were reviewed in November 2022 to identify modules related to climate change. The web-based survey was administered through Redcap (18) and, to prevent multiple submissions, all respondents were advised to complete the survey only once.

Ethical approval was granted by the Research Ethics Committee "Azienda Ospedaliero-Universitaria Consorziale Policlinico," protocol number "009129–24/04/2023."

2.2 Questionnaire development

Development of the questionnaire was informed by a literature review. Overall, the questionnaire comprised a total of 41 questions, 20 of them used for constructing the Knowledge, Attitudes and Practices (KAP) score. A KAP design was chosen to promote comparability of the results and to facilitate result interpretation and dissemination. The Knowledge section focused on common climate change misconceptions (19), major international agreements and

policies, and basic notions about the link between the eco-climate crisis, human health and infectious diseases. One point was awarded for each correct answer or for responses demonstrating a positive attitude or practice toward climate action, with a maximum achievable score of 20.

The questionnaire also featured a section on eco-anxiety, comprising seven items structured as Likert-style questions. This section delved into the participants' concerns regarding their own or their families' direct involvement in major catastrophic events linked to climate change. Each question comprised 5 graded answers, to which a score ranging from 0 ("not concerned") to 4 ("extremely worried") was assigned. As a result, eco-anxiety was quantified with a score ranging from a minimum of 0 to a maximum of 35 points.

Additional items focused on demographics (4 items) occupation-related information (8 items) and zoonosis and spillover risk (2 items). Full question list is provided in the Supplementary Tables 1, 2.

2.3 Statistical analysis

A descriptive analysis was performed to define the distribution of demographics and occupation-related characteristics of the sample. Different typologies of postgraduate medical specialties were classified into clinical, non-clinical and surgical areas as for the Italian Ministry of University and Research classification (DM 68/2015). For numerical variables, normality was assessed with the Shapiro–Wilk test. Missing data points were identified and documented during the descriptive analysis phase.

KAP score was used as the dependent variable. Spearman-rank test was used to compare groups for continuous variables, while a Kruskal-Wallis test was applied for categorical variables. An ordinal regression model was implemented as follows. KAP score was considered as a dependent variable and each one of the available factors at the baseline evaluation as independent variables (univariate analysis). In the multivariate analysis factors with a p-value <0.05 by univariate analysis were included. Multicollinearity among covariates was assessed through the variance inflation factor, taking a value of 2 as cut-off to exclude a covariate. However, no variable was excluded according to this pre-specified criterion, suggesting that missing data did not significantly affect the multicollinearity of the model. Odds ratios (ORs) as adjusted odds ratios (adj-ORs) with 95% confidence intervals (CIs) were used to measure the strength of the association between factors at the baseline and KAP score. All statistical tests were two-tailed and statistical significance was assumed for a p-value <0.05. Statistical analyses were performed using R Statistical Software (v4.1.3; R Core Team 2021) in R Studio Version (20).

3 Results

3.1 Demographics

Out of a total of 613 individuals who were invited to complete the questionnaire, 605 provided their consent to participate in the study. The study population encompassed 264 medical students, 194 residents, and 108 specialists. The majority of the medical residents and specialists were employed in the clinical area ($n = 206$, 60.4%), followed by area of clinical services ($n = 49$) and surgical area ($n = 33$). The average age was 27.6 years (interquartile range, Q1-Q3, 24.1–31.3), and 58.2% ($n = 352$) of the participants identified as female. The participants were spread across different regions of Italy, including 100 (16.5%) from Central Italy, 174 (28.8%) from Northern Italy, and 314 (51.9%) from Southern Italy.

3.2 Knowledge

Two-hundred fifty seven participants (42.5%) were not able to identify the limits to global temperature increase set by the Paris Agreement (21), and 59.2% ($n = 358$) did not agree that canceling the debt of poorer countries could constitute a valid climate justice policy. Only 16.4% ($n = 99$) could identify influenza as a zoonosis, despite 71.2% ($n = 431$) correctly recognized deforestation as a driver for spillover. Misconceptions about climate change were common: 45.5% of the sample did not express disagreement with the statement "climate change is caused by sunspots" and 15.4% ($n = 93$) either agreed (5.9%, $n = 36$), strongly agreed (2.5%, $n = 15$), or could not take a position (6.45%, $n = 39$) regarding the sentence "The climate change is part of a natural cycle that has always existed, where human activities play only a marginal role." Detailed responses to all questionnaire items, stratified by occupation, can be found in the Supplementary material. Curricula of all Italian medical universities available online were reviewed on September 15th, 2023. We found only one institution (University of Turin) offering a course explicitly targeting the impacts of climate change on human health.

3.3 Attitudes and practices

Almost all of our population ($n = 601$, 99.3%) considered the climate crisis an important and urgent problem (Figure 1) and did not agree on the fact that governments are taking adequate action to address it ($n = 535$, 88.43%). Despite this, only 79 (11.6%) people thought that there is nothing left to do to limit the consequences of the eco-climate crisis. In terms of practices (Figure 2), the majority of the population declared to be "available" or "very willing" to adopt carbon-saving lifestyle choices ($n = 535$, 88.4%) and to participate in advocacy activities among coworkers ($n = 540$, 89.3%) and the general population ($n = 559$; 92.4%), while they were generally less prone to engage in civil disobedience ($n = 279$, 46.1%) and to introduce an exam dedicated to climate change and health into medical curricula ($n = 406$, 67.1%).

3.4 Eco-anxiety

The fear that the eco-climate crisis would impact the personal life of the respondents and/or of their family member was high, with a median overall eco-anxiety score of 26/35 (Q1-Q3, 22.3–28.0). In particular, 530 (87.6%) participants declared to be concerned (38.3% "worried" and 49.3% "extremely worried") that human activities will lead to new pandemics in the near future, and 79.5% (32.9% "worried" and 32.9% "extremely worried") were afraid that vector-borne diseases

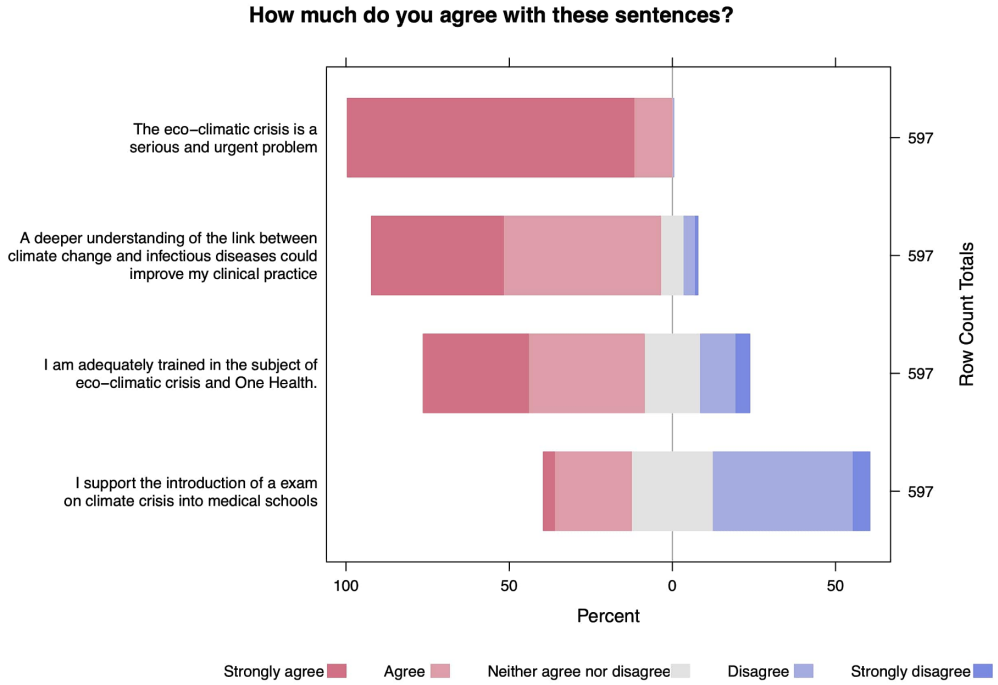

FIGURE 1
Likert-style responses to selected questions.

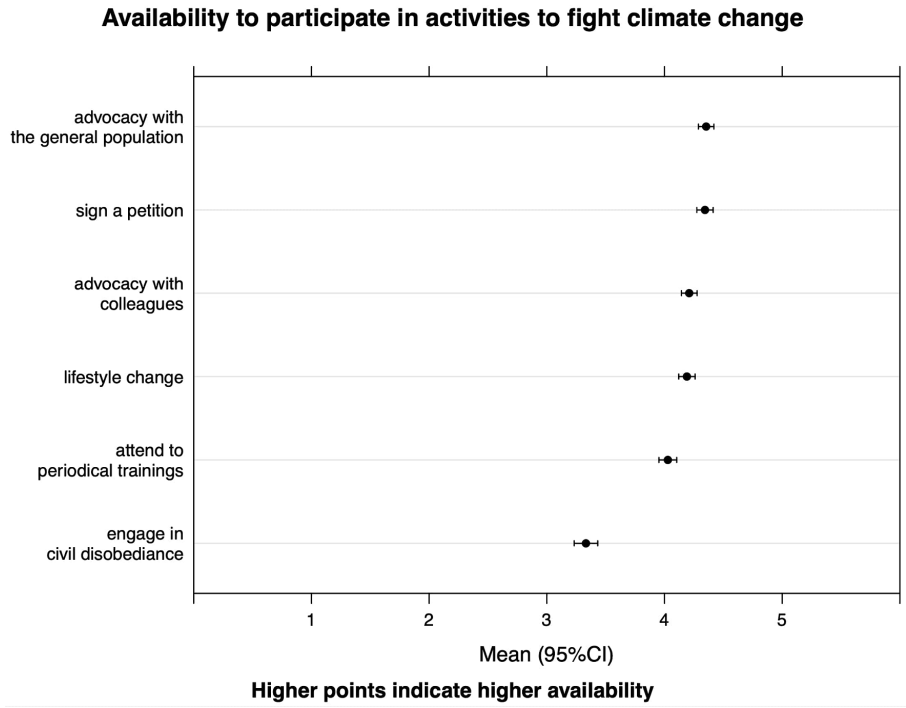

FIGURE 2
Willingness to engage in selected activities in support for the climate. Each dot represents the mean of the responses from 1 ("minimum availability") to 5 ("maximum availability"). Tick lines show 95% confidence intervals.

such as malaria or dengue will become endemic in Italy. Also, 83.9% (39.2% "worried" and 44.7% "extremely worried") manifested concern that climate change will lead to political instability and wars. Almost the entirety of our population (94.4%, $n = 571$) declared to be afraid (32.4% "worried" and 62% "extremely worried") that the eco-climate crisis will affect the health of present and future generations.

TABLE 1 Descriptive statistics, bivariate analysis and ordinal logistic regression for higher KAP score.

	Overall ($N = 605$)	KAP score, Median (Q1-Q3)	p-value for higher KAP score[a]	Ordinal regression analysis aOR (95% CI), p-value
Gender				
Female	352 (58.2%)	15 (13–16)	**0.012**	Ref
Male	246 (40.7%)	14.5 (12–16)		0.831 (0.62–1.11) $p = 0.215$
Non-binary	4 (0.7%)	17 (16.5–17)		2 (0.32–12.15) $p = 0.443$
Age				
Median [Q1, Q3]	27.6 [24.1, 31.3]	–	0.149	–
Area				
Central Italy	100 (16.5%)	15 (13–16)	0.357	–
Northern Italy	174 (28.8%)	15 (13–16)		–
Southern Italy	314 (51.9%)	15 (12.25–16)		–
Missing	17 (2.8%)	–		–
Position				
Student	264 (43.6%)	15 (12–16)	0.518	–
Medical resident	194 (32.1%)	15 (13–16)		–
Medical specialist	108 (17.9%)	15 (12–17)		–
Other	39 (6.4%)	15 (13–16.5)		–
Medical area ($n = 341$)				
Clinical area	206 (60.4%)	15 (13–16)	0.14	–
Clinical services area	49 (14.4%)	14 (11–16)		–
Surgical area	33 (9.7%)	13 (12–16)		–
Missing	53 (15.5%)	-		–
Eco-anxiety score				
Median [Q1, Q3]	20.0 [17.0, 22.0]	-	**<0.001**	1.29 (1.24–1.35), **p < 0.001**
Trust in government action to mitigate climate change				
No	535 (88.4%)	15 (13–16)	**<0.001**	Ref.
Yes	70 (11.6%)	13 (11–15)		0.51 (0.32–0.79), **p = 0.003**
Belief that nothing can be done to contrast the climate crisis				
No	574 (94.9%)	15 (13–16)	0.616	–
Yes	31 (5.1%)	15 (12–16)		–

[a]Spearman test and Kruskal-Wallis test, as appropriate. Statistical significant results ($p > 0.05$) are highlighted in bold.

Cronbach's alpha for eco-anxiety score was 0.84 (95%CI 0.82–0.86), indicating high level of internal consistency.

3.5 Bivariate and multivariate analysis for high KAP score

As shown in Table 1, the variables that resulted associated with higher KAP score at bivariate analysis were being female ($p = 0.012$), demonstrating higher eco-anxiety, and lower trust in government action to mitigate climate change. Multivariable ordinal regression analysis confirmed the association with low trust in government action (aOR 0.51, 95%CI 0.32–0.79) and higher eco-anxiety (aOR 1.29, 95%CI 1.24–1.35). The overall Cronbach's alpha for the KAP score, calculated for a data set of 605 respondents, was 0.71 (95%CE 0.67–0.74), indicating an acceptable level of internal consistency.

4 Discussion

In this study, Italian students of medicine and young doctors showed a positive attitude toward climate change, despite a demonstrating a substantial gaps in knowledge about its causes and consequences on human health. Four respondents out of five were not able to identify the 1.5°C threshold included in the Paris Agreement. Misconceptions about climate-change causes were widespread, including almost half of the respondents attributing a causative role to sunspots and an alarming one in six participants who believed that human activities played only a marginal role in shaping the current climate scenario. Also, only six in 10 persons being able to identify intensive farming as a risk factor for spillover, and a stunning 84% of the sample not being able to recognize influenza as a zoonotic disease. Also, despite the recent scientific debate fostered by the pandemic (22), the majority of the population did not

classify COVID-19 as a disease with zoonotic origins (23, 24). To the best of our knowledge, this study represents the first attempt to assess the awareness of physicians and medical students regarding the influence of human-induced ecological degradation on the susceptibility to infectious diseases, which represent roughly 75% of all newly emerging infectious diseases described in the last four decades (25).

The poor knowledge reported in our study is consistent with other surveys conducted among Italian high school students (26), and with a multinational survey conducted on the general population (27). Moreover, our rate of respondents neglecting the role played by human activities is almost identical to the one reported in a large multinational survey conducted on 4,654 health professionals in 2020 (28). Compared to this study, however, our sample exhibited a higher level of engagement (99.3% vs. 75%), with almost all respondents acknowledging the urgency to address the impact of the eco-climate crisis on human health.

In this study, the concern that the eco-climate crisis will have an increasingly negative impact on participant's health was widespread. Italy is highly vulnerable to climate change, and extreme weather events—such as the 2023 Northern Italy drought, Emilia-Romagna floods, summer wildfires and heathwaves (29). Also, incidence of vector-borne illnesses like Lyme disease (30) and dengue fever (31) is increasing, and clinicians are already witnessing rising heat-related mental health risk (32). All this is fostering a general rise in climate-related fear and anxiety (33).

A peculiar finding of our study is a strong correlation between eco-anxiety with higher eco-climate awareness and positive attitude toward eco-climate crisis. This finding is in line with a multinational survey exploring the correlation between climate-sensitive mental health issues and pro-environmental action (34). Also, similar surveys conducted on other key climate change stakeholders, such as government officers, private sector employees, and NGO operators, showed similar results in terms of climate action engagement.

Physicians occupy a unique position in society, providing them with a profound opportunity for climate action (12). Engagement of the medical community into advocacy and climate activism might accelerate system change, considering their social respectability and their individual experience as daily witness of the effects of climate change on human health (35). This can be achieved on both the individual and societal level, by prescribing low-carbon lifestyle choices and advocating for broader political engagement. To achieve this, physicians should have basic knowledge of the key drivers of human-induced climate change, as well as a robust understanding of how increasingly warmer global temperatures and biodiversity loss impact various aspects of human health. These aspects include, but are not limited to, heat stress risk, mental health, food security, and the suitability for water-borne and vector-borne diseases, and pandemic risks (36).

Our study suggests that Italian doctors are sensitive to the threat posed by the eco-climate crisis and are prone to be engaged into climate action. However, they still lack specific education. Medical institutions and scientific societies are recognizing that it is impossible to separate human health from the health of other living beings and the entire planet. Our results emphasize that is essential to adopt a more comprehensive approach to health such as that the one conceptualized by Planetary Health (37), which leads us to seek the highest standard of health and equity by taking into account both human systems (such as the political, economic and social ones) and the natural systems of the planet. The findings and methodology of this study can be applied to other countries by serving as a model for assessing the knowledge, attitudes, and practices regarding climate change and its health impacts among medical professionals. The survey approach, including the KAP score and eco-anxiety assessment, can be adapted to different cultural and educational contexts to identify gaps in climate-related medical knowledge and the emotional responses of medical students and professionals. This can inform targeted policy changes in medical curricula to better equip future physicians globally to address climate-related health issues, potentially involving them actively in mitigation strategies. In this context, the COVID-19 pandemic contributed to raise awareness among healthcare personnel about the impact of ecological degradation on human health, while presenting an unprecedented opportunity to accelerate global climate mitigation efforts (38).

The limitations of this study are notable and should be carefully considered when interpreting the results. The use of convenience sampling may lead to selection bias, as it might not accurately reflect the broader population of Italian medical professionals and medical students. To minimize selection bias, we implemented a multicenter design encompassing 19 Italian regions and conducted a multivariate analysis to control for potential confounding factors. This method also potentially limits the generalizability of the findings to other medical communities or geographical regions, even with the relatively high numerosity achieved by the study. Also, the reliance on self-reported data can introduce response bias, where participants might provide answers they perceive as socially acceptable rather than those that reflect their true behaviors and beliefs. Furthermore, the cross-sectional design of the study captures attitudes and knowledge at a single point in time, which means it cannot account for changes over time or establish any causal relationships. Finally, while the questionnaire was informed by a literature review, the possibility of overlooking key aspects of climate change knowledge or attitudes that are relevant to medical professionals cannot be discounted. However, this limitation was counterbalanced by a good internal consistency of the outcome score.

5 Conclusion

In our study, despite showing poor knowledge of Planetary Health and climate change drivers, Italian physicians and medical students demonstrated interest and considered the issue important. Furthermore, they showed a generally positive attitude and willingness to engage in pro-environmental activities. Policymakers should adopt a new approach to medical education that equips doctors with the ability to recognize climate and ecological risks and integrate principles of planetary health into their clinical practice. The medical education system should empower our physicians to define the boundaries within which humanity can thrive.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by "Azienda Ospedaliero-Universitaria Consorziale Policlinico," protocol number "009129–24/04/2023." The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FS: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. FrG: Conceptualization, Supervision, Validation, Writing – review & editing. LG: Supervision, Writing – original draft, Writing – review & editing. GS: Conceptualization, Data curation, Writing – review & editing, Methodology, Supervision. AC: Data curation, Writing – review & editing. AV: Data curation, Methodology, Writing – review & editing. SG: Data curation, Writing – review & editing. LF: Data curation, Writing – review & editing. GG: Data curation, Writing – review & editing. RN: Data curation, Writing – review & editing. AA: Data curation, Writing – review & editing. IR: Data curation, Writing – review & editing. FF: Data curation, Writing – review & editing. LM: Data curation, Investigation, Methodology, Writing – review & editing. II: Data curation, Investigation, Writing – review & editing. SaM: Data curation, Investigation, Writing – review & editing. SiM: Data curation, Writing – review & editing. NV: Data curation, Supervision, Validation, Writing – original draft, Writing – review & editing. FeG: Supervision, Visualization, Writing – review & editing. RI: Supervision, Validation, Writing – review & editing. AS: Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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EDITED BY
Jacqueline G. Bloomfield,
The University of Sydney, Australia

REVIEWED BY
Luca Valera,
University of Valladolid, Spain

*CORRESPONDENCE
Ebba Malmqvist
ebba.malmqvist@med.lu.se

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Bridging disciplines-key to success when implementing planetary health in medical training curricula

Ebba Malmqvist[1]* and Anna Oudin[1,2]

[1]Division of Occupational and Environmental Medicine, Lund University, Lund, Sweden, [2]Division of Sustainable Health, Umeå University, Umeå, Sweden

Planetary health is being or should be added to medical training curricula in accordance with association consensus. Several articles published in recent years have addressed concern on the implementation, and the challenges that can occur if not addressed properly. This scoping narrative literature review focuses on planetary health as a concept, as well as challenges and suggested solutions to address these challenges. Planetary health is an important concept and needs to be addressed in all medical training. We found that one main challenge is implementation without ensuring the right competences and resources. Medically trained teachers set out to understand and teach complex natural and social systems. At some institutions the time allocated to teach planetary health is limited or non-existent. Case studies and student led teaching are solutions suggested, while other argue that true interdisciplinarity by inviting experts are more in line with what we expect from other subjects. In conclusion, the roots of planetary health, the enormous health risks at stake and nature of the subject requires medical training to adopt a true inter/trans-disciplinary approach to succeed. It might not be expected for all students to become planetary health experts, but all need a general understanding of the most important aspects and values.

KEYWORDS

planetary health, one health, medical training, medical curriculum, climate change

1 Introduction

Planetary health is increasingly added to the medical training curricula in accordance with the international medical training association consensus. This is very promising, but several articles have raised challenges if the topic is not addressed properly.

1.1 What is the planetary health concept and where did it come from?

This little blue planet, perfectly formed for human life, has been our home for thousands of years. Earth systems enabled human life under the best conditions, a state that lasted for around 10,000 years, referred to as Geological period "Holocene." The anthropogenic (human-made) impacts on the planet's natural systems have led to civilizational successes of the past decades (e.g., increasing life expectancy and reducing poverty) coupled with negative global developments (e.g., loss of biodiversity, pollution and climate change). These trends are in an historical perspective

quite new, and often coupled with industrialization toward the end of the 19th century with an increase particularly from the 1950s onwards (1).

The alarm bell started in the early 1960s with Rachel Carson's book Silent Spring on man-made chemicals leading to a decline in birds (2). In 1972, Dr. Sargent wrote about the connection between the 'planetary life-support systems' and health and well-being (3). At about the same time, Gennady Tsaregorodtsev called for a new integrative hub of science called 'planetary public health' to better understand the evidence on the human health impact of environmental degradation (4). In 1980, Friends of the Earth expanded the World Health Organization definition of health, stating: "*health is a state of complete physical, mental, social and ecological well-being and not merely the absence of disease – personal health involves planetary health*" (5).

Some scholars highlighted that the idea that planetary health wasn't a new concept; rather, these ideas have been deeply embedded within Indigenous cultures for centuries (6). The first Navajo woman surgeon said "*human health is dependent upon planetary health and everything must exist in a delicate web of balanced relationships*" (7). We should thus be humble when we present planetary health as a novelty topic or 'new discipline'.

Planetary health can be seen as a concept that affects all healthcare providers and understood by our ancestors. This relates to indigenous knowledge, but also western ancient roots had a medical interest in the environment. The Hippocratic text *On Airs, Waters, Places* advised physicians to attend to all aspects of the environment. It took some decades for the planetary health term to become a term in mainstream modern medicine since its reintroduction in the 1980's. The success and widespread notion of the concept came with the highly-cited 2015 keystone report by the Rockefeller-Lancet Commission on Planetary Health (1). The report defined planetary health as "*the health of human civilization and the state of the natural systems on which it depends*," with its stated goal to find '*solutions to health risks posed by our poor stewardship of our planet*' (1), the term planetary health (and what it represents) had finally entered the lexicon of mainstream medicine. The *Commission* report calls for the application of interdisciplinary knowledge, as well as input from healthcare professionals to play important its roles by supporting environmental and social sustainability (1).

1.2 Planetary health in medical training curriculum

Medical schools are now being called to develop physicians with the skills necessary to navigate the planetary health crisis, including the natural science and policy transformation necessary. It has been argued that a physician's place is at the individual patient's bedside, but now also to preventatively advocating for public health beyond the bedside. Numerous medical societies and organizations have called climate change the single greatest threat to human health (8, 9). Medical students have been pushing for integration of climate health content in curricula to equip them to adequately care for patients in a rapidly changing environment (10).

Still the medical schools have failed to adapt fast enough. The International Federation of Medical Students' Associations conducted a survey in 2019 and 2020 in 2817 medical schools in 112 countries. Only 15% of medical schools had incorporated climate change and health and only 11% added air pollution and health into the curriculum (11). Another study covering 45% of the UK medical schools found a large disparity in the education that medical students receive on planetary health and sustainability topics, with many schools not prioritizing the field. The extent of teaching varied considerably among courses with a mean estimate teaching time of only just over two hours (12). Another study found that faculty often lack the knowledge to teach this emerging subject (13). In a US study using in-depth interviews found personal expertise as a barrier in applying climate change aspects in their teaching material or knowledge often bound to a specific person (14).

1.3 Aim

This narrative review article aims to give the reader a deeper understanding of planetary health as a concept and to explore challenges and solutions related to the interdisciplinary aspects of planetary health in medical curricula.

2 Method

This mini review used a narrative review approach which is considered appropriate when in relation to a collection of quantitative studies that have used diverse methodologies or theoretical frameworks. Narrative reviews are a useful way of linking together studies on different topics related to a new concept or to understand the historical perspective of a new concept (15). We conducted a search on PubMed on the term `planetary health' and ´education´, ´medical curricula´ or `interdisciplinary` and ´transdisciplinary´. We also expanded the references in the articles we had found by so-called citation searching, and snowball searching. As it is a narrative mini-review we had to make limitations if similar statements had already been included.

3 Results

3.1 Inter/transdisciplinary approach vital to planetary health

In the result section we will first highlight key finding on importance of inter/trans/multi-disciplinary in medical training of planetary health. In the next chapters we will take a deeper look into some disciplines that have been addressed in the literature.

Several frameworks to address planetary health into medical curricula has been suggested (16). This includes the Planetary Health Report Card, a student developed metric tool for evaluating and improving the planetary health content (17). Sustainable Healthcare Education network has developed methods of including planetary health literacy in clinical training, such as deeper understanding on how the environment is degraded, how this impact our health and what actions can lead to improvement (18). Along with learning the science behind environmental health, students need to develop skills to lead and advocate for community change according to the Association for Medical Education in Europe consensus (19). One suggested way to get students involved is working with case studies (20). Building students' commitment to planetary health approaches requires engaging students

in interdisciplinary active learning of a transformative systems-based paradigm (21). Other concepts suggest expanding interdisciplinarity to indigenous reciprocal stewardship of our natural surroundings (22, 23). Planetary Health Education Framework also highlights the importance of transdisciplinary knowledge (including epistemological diversity) (24). Climate Crisis and Clinical Practice initiative also highlights the need for medical training to include a multidisciplinary approach (9).

The One Health and Planetary Health approaches are increasingly influencing the field of medicine way of thinking in everyday clinical practice and research (25). Both approaches represent the integrative consideration of health topics against the background of other sciences. Particularly characteristic of planetary health are, among other things, the aspects of a transdisciplinary approach (26), and this was also the findings of the methods/frameworks we identified above. Another narrative review also had similar results of the need to work interdisciplinary when including planetary health in medical training. They also highlighted the importance to work across sectors to reach a better understanding of the interactions between humans and its surrounding environment (27). Based on the seemingly importance of inter/trans-interdisciplinary curricula we will highlight some important disciplines we found in the literature and how they could be addressed. This should not be seen a complete list of an ever-expanding field.

3.1.1 Natural sciences

With global health burdens shifting from infectious to non-communicable diseases (NCDs), we need greater emphasis on the health-mediating role of lifestyle and the human-manufactured threats to life within the biosphere (28). Irreversible changes to our environment have already occurred that are affecting the health of the world's population, also known as triple crisis. Environmental pollution can be detected in the most remote areas of the earth (29), and the consequences of climate change are measurable and visible (30). The natural areas are diminishing at high speed caused by anthropogenic (human made) environmental changes to the land (31).

The concept of Planetary health in the Rockefeller report was influenced by (32, 33) models of planetary stress limits. The boundaries represent components of Earth system critically affected by anthropogenic activities and relevant to Earth's overall state. For each of the boundaries, control variables are chosen to capture the most important anthropogenic influence at the planetary level of the boundary in focus. So-called tipping points were quantified, the exceedance of which results in the relatively abrupt and irreversible changes for the Earth system. These changes can challenge the socio-ecological resilience of societies and be catastrophic for societies and individuals alike (32).

For planetary health action to happen Anthony McMichael, one of the first epidemiologists to study the links between climate change and human health says: "*The health sector*," McMichael demanded, "*must lift its gaze to bigger, ecological horizons. This will require […] an ability to collaborate with unfamiliar disciplines*" (34).

The future leaders in medicine need to understand the basis of our natural life-supporting systems and their boundaries. This includes a profound knowledge of natural laws on which our life support systems depend (22, 23).

3.1.2 Political and economy sciences

A central characteristic of planetary health are also the terms of the urgency of transformative measures (35). It was physicians and the nascent public health movement of the 19th century that demanded the reforms in urban sanitation (36), workplace hazards (37), and battled the tobacco industry and often indifferent governments for tobacco controls (38). But never have the stakes been higher, or the scale greater, than what ecological crises now entail. The survival of our societies as we know them depends on medically informed political responses to the disruption of our planet's human life–support systems. This will require augmented skills in health promotion principles, and deeper knowledge for health professionals to politically mobilize through social, economic and environmental advocacy for urgent and major reforms (39). The World Health Organization ask for health actors that can identify and accelerate those climate change mitigation actions that brings the greatest health gains, including the promotion of healthy urban transport systems and diets (40).

The Association for Medical Education in Europe (AMEE) has made a consensus statement *Planetary health and education for sustainable healthcare* intended to inform national and global accreditation standards, planning and action at the institutional level as well as the role of individuals in transforming health professions education. They state: "*health professions education must equip undergraduates, and those already qualified, with the knowledge, skills, values, competence, and confidence they need to sustainably promote the health, human rights, and well-being of current and future generations, while protecting the health of the planet.*" As an example they mention the skills to model co-benefits to people and planet of socio-ecological informed health programs (19). Changes that are implemented in the spirit of climate protection usually contain an additional benefit (co-benefit) for health and vice versa as exemplified by environmentally friendly forms of transport and other lifestyle factors (41). Skills to understand these co-benefits and to quantify them also in economic terms puts planetary health on par with other agendas in political and economic discussions.

3.1.3 Social sciences

The consequences of human interaction with the earth's natural systems are diverse, interconnected, and global because of globalization and the sheer scale of human resource use and consumption. The fact that impact can be both local and global, and often unevenly distributed, makes environmental justice central in planetary health. Rich nations in the global north are primarily responsible for the transgression of planetary boundaries, such as causing significantly higher CO_2 emissions. But the effects of which are felt most acutely by poorer countries in the global south (30). Social determinants of health can either improve or exacerbate vulnerability to poor health outcomes associated with climate change, pollution, and access to green areas. Knowledge of vulnerable groups by age, culture and socio-economy and other determinants are important to consider when setting health recommendations (42). This makes it important to get a deeper understanding of inequality and justice perspectives of planetary health.

3.1.4 Medical science

Resident physicians need to be equipped to care for patients affected by climate-mediated disease and advocate for solutions to the climate crisis. One approach is to organize evidence-based topics in climate and health by medical subspecialty and integrated them into pre-existing lectures in the longitudinal, outpatient lecture series (43). This will still require that students have some background knowledge on ecosystem services and planetary boundaries. Humans are inter-linked with the necessary life-support systems of this planet. In total

about one quarter of all global preventable premature death is due to environmental risk factors (44).

Future physicians must be aware of, for example changes in infectious disease patterns due to lack of clean air and changing weather patterns affected by flooding and temperatures. The planetary boundary *novel entities* relate to released unsafe chemicals which are directly linked to health. Novel entities can be exemplified by the release of Per-and polyfluoroalkyl substances (PFAS) which can be present in municipal drinking water and reduce antibody levels in response to vaccination (45). Another planetary boundary is the aerosols which relates to air pollution of combustion particles that can penetrate the alveolar blood-gas exchange and causes about 7 million premature deaths a year (44). The planetary boundary, nitrogen excess, impacts ecosystems by eutrophication and more directly humans by drinking water quality. The health impacts is early in life the blue baby syndrome and later in life an increased risk of cancer (46). Planetary health is also not only about global changes but to understand local exposures. Future physicians need to develop a system thinking of these complex interrelationships with patients in their entire environment and how social determinants can impact health effects.

4 Discussion

Gaining support from medical school faculty can be a major challenge. In a study of eleven medical schools in UK, one educator said that sustainable healthcare '*was at first seen as one of my pet extra projects*' (47). It was suggested that with time as more residency programs incorporate environmental-related content into their curricula, faculty will become more familiar with these important topics and allocate time and resources (43). Moreover, an overarching paradigm of higher education often upholds ideologies of individualism and meritocracy and a shift toward skills in compassion-knowledge-reflection are highly needed (22). The need of planetary stewards was put forward by 126 Nobel prize laureates in their 2021 statement *Our planet, our future*. One suggested way of getting an increased understanding of our interlinkage with our planet and thus the importance of biodiversity is getting the subject near the heart of the students. One example is the understanding of biomimetics for curing diseases as one third of medications used in healthcare originate from nature, the development of future cures depends on preserved diversity (48). For others it can be beneficial with the introduction of the ecosystem framework which categorize the benefits of healthy functioning ecosystems that regulate (climate), support (water, food, medicine, air) and provide services for human health and wellbeing (49). Even though this concept still has an aspect of anthropocentric (human-centered) thinking seeing nature purely as goods, it can be a steppingstone for those furthest from a more eco-centric planetary health thinking.

Teaching planetary health to students presents unique challenges, especially when some students may deny the human impact on climate change. This mirrors societal skepticism, where vocal climate change deniers exist despite overwhelming scientific consensus. It is crucial for lecturers to be exceptionally knowledgeable, capable of engaging in informed discussions with students who question the human role in climate change and planetary health. Most students have on the other hand grown up aware of insufficient actions against climate change, mass species extinctions, and pervasive pollution. This background can lead to feelings of hopelessness for some students, making the topic particularly heavy during their early clinical training years. Therefore, it is imperative that educators in planetary health maintain a high level of expertise. They must be equipped to address the skepticism of some students while also supporting those who may feel overwhelmed by the gravity of environmental issues (50). Balancing these perspectives with scientific rigor and empathy is essential for fostering a constructive and educational environment.

Using only medically trained faculty is deemed to fail in teaching a subject such as planetary health. Management of "wicked problems," messy real-world problems that defy resolution, requires thinkers who can transcend disciplinary boundaries, work collaboratively, and handle complexity and obstacles (51). Medical training would benefit from including faculty researchers from a range of disciplines across the natural, social and health sciences (52, 53). An in-depth study of one medical school on successes and pitfalls in introducing climate change into the medical curricula recognized the importance of climate and health literacy on all levels, also those with the power to make curricular decisions (54).

We acknowledge that this article is a narrative report and should not be seen as a systematic review covering all relevant studies in the field. The selection and interpretation of studies rely on our perspective, potentially introducing bias, neither was the study quality assessed systematically. Despite these limitations, our study can provide an overview of the emerging fields of planetary health and identify some challenges and suggested solutions.

5 Conclusion

In conclusion, the roots of planetary health, the enormous health risks at stake and nature of the subject requires medical training to adopt a true inter/trans-disciplinary approach to succeed. It might not be expected for all students to become planetary health experts, but all need a general understanding of the most important aspects and values.

Author contributions

EM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AO: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Michelle McLean,
Bond University, Australia

REVIEWED BY
Mona Sarfaty,
George Mason University, United States
Jonathan Patz,
University of Wisconsin-Madison,
United States

*CORRESPONDENCE
Harriet Okatch
✉ okatcharriet@gmail.com

†These authors have contributed equally to this work and share last authorship

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Climate change and its impact on health: a global collaborative learning model

Harriet Okatch[1]*, Patricia A. Remshifski[2], Anita Fennessey[3], Haley Campbell[4,5], Sivia Barnoy[6], Jason Friedman[7], Stephen B. Kern[8], Rosemary Frasso[1,9], Cecilia Sorensen[4,5,10], Tami Bar-Shalita[11†] and Louis N. Hunter[12,13†]

[1]Jefferson College of Population Health, Thomas Jefferson University, Philadelphia, PA, United States, [2]Department of Speech-Language Pathology, Jefferson College of Rehabilitation Sciences, Thomas Jefferson University, Philadelphia, PA, United States, [3]Jefferson College of Nursing, Thomas Jefferson University, Philadelphia, PA, United States, [4]Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, NY, United States, [5]Global Consortium of Climate Change and Health Education, Mailman School of Public Health, Columbia University, New York, NY, United States, [6]Department of Nursing, School of Health Professions, Faculty of Medical & Health Sciences, Tel Aviv University, Tel Aviv, Israel, [7]Department of Physical Therapy, School of Health Professions, Faculty of Medical & Health Sciences, Tel Aviv University, Tel Aviv, Israel, [8]Department of Occupational Therapy, Jefferson College of Rehabilitation Sciences, Thomas Jefferson University, Philadelphia, PA, United States, [9]Asano-Gonnella Center for Research in Medical Education and Health Care, Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA, United States, [10]Department of Emergency Medicine, Columbia University, New York, NY, United States, [11]Department of Occupational Therapy, School of Health Professions, Faculty of Medical & Health Sciences, Tel Aviv University, Tel Aviv, Israel, [12]Jefferson College of Health Professions, Thomas Jefferson University, Philadelphia, PA, United States, [13]Department of Physical Therapy, Jefferson College of Rehabilitation Sciences, Thomas Jefferson University, Philadelphia, PA, United States

To address the health effects of climate change, leaders in healthcare have called for action to integrate climate adaptation and mitigation into training programs for health professionals. However, current educators may not possess sufficient climate literacy and the expertise to effectively include such content in their respective healthcare curricula. We, an international and interprofessional partnership, collaborated with experts to develop and deploy curriculum to increase health educators' and graduate health profession students' knowledge and competencies on climate change. In a tri-step process, the first phase included recruiting interested faculty members from two institutions and varying health professions. In phase two, faculty members collaborated to develop a faculty symposium on climate change including educational competencies required of health professions, practice standards, guidelines, and profession-specific content. Symposium outcomes included broader faculty member interest and commitment to create an interprofessional climate change course for healthcare graduate students. In phase three, course development resulted from collaboration between faculty members at the two institutions and faculty members from the Global Consortium on Climate and Health Education (GCCHE), with course objectives informed by GCCHE competencies. Climate experts and faculty members delivered the course content over a 10-week period to 30 faculty members and students representing seven health professions, who were surveyed (n=13) for feedback. This course can serve as an example for international collaborators interested in developing climate change courses for health profession students. Lessons learned in this process include: climate change novice faculty members can develop impactful climate change courses; students and faculty members can be co-learners; diverse representation in course attendees enriches the learning experience; and collaboration is key.

KEYWORDS

climate change, interprofessional, healthcare, curriculum, international, course development, symposium

Introduction

The World Health Organization (WHO) and the Intergovernmental Panel on Climate Change have highlighted the direct negative impact of climate change on the environmental determinants of health, including sufficient safe water, food and shelter (1, 2). These climate-related events are accompanied by myriad adverse health effects that can overwhelm healthcare systems and pose challenges to health practitioners who may not have had training in preventing, diagnosing and treating climate-related health. The WHO predicts that climate change will cause approximately 250,000 additional deaths per year between 2030 and 2050 (1). Since climate change is associated with increases in morbidity from infectious, cardiovascular, respiratory and neurological diseases (3), leaders in healthcare have called for action to integrate climate adaptation and mitigation into health professions education (HPE) (4–7).

Although the climate crisis demands that today's health professionals understand its effects on health and implications for treatment (1, 8), healthcare providers are, however, not trained or equipped to address climate change impacts but have reported interest in developing the appropriate knowledge and skills (9–11). Globally, however, climate change education is generally not mainstream or mandatory, hence current health professional students may not graduate with the skills needed to address climate change in their future roles (8, 12). Health professionals may not intuitively envision their role in climate change education and advocacy for policies that would protect their patients/clients. This may be because the educators themselves are not proficient in climate change issues since most professional educational standards do not currently require that curriculum include climate change (13).

Existing climate change and health curricula have utilized varying design approaches and have been developed for specific audiences (14–16). Recognizing that faculty members may have time constraints with heavy teaching responsibilities, established research agendas in areas independent of climate change, and limited climate expertise, we utilized a global collaborative model to develop a climate change course that places faculty members both as educators and learners. The target audience for this pilot course included both faculty members and students from a range of health professions. Here, we describe the processes undertaken by a team of interdisciplinary educators from three institutions in two countries to increase climate literacy for health professions faculty members and students.

Increasing climate literacy

A triphasic process, described below, was used to increase climate literacy among faculty members. Figure 1 summarizes the phases, activities, and outcomes involved in this unique model for increasing climate literacy for both faculty members and students.

Approach

Phase 1: Faculty member recruitment

In 2018, The Jefferson Israel Center was established between Tel Aviv University (TAU), Israel, and Thomas Jefferson University (Jefferson), United States, with the goal to partner in academic and clinical research. Through this existing partnership and several meetings, faculty members identified two major priorities: Develop bilateral student exchange and co-host a virtual event. These initial meetings allowed faculty members to meet, present their areas of research interests and current work, and identify an area of interest to collaboratively research.

Faculty members from both academic institutions attending the planning meetings represented Occupational Therapy, Physical Therapy, Speech-Language Pathology, and Nursing. They decided to focus academic and research collaboration on the neglected area of climate change and natural disaster management from an interprofessional perspective. The final group of faculty stakeholders comprised healthcare faculty members who were interested and committed to incorporating climate change and health into graduate (Masters) HPE.

Phase 2: Symposium on climate change and health education: planning and hosting

Faculty members from the two academic institutions collaborated to plan a global educational symposium as an interprofessional opportunity for participants to learn about impact of climate change and climate-related disasters on health, especially for vulnerable populations. This educational symposium was entitled "Educational Symposium on Climate Change 2022: An Introduction to the Role of the Healthcare Professional during Climate Change Events." It took place in late May at a mutually acceptable time for US and Israeli participants. It was held in-person at each institution as well as virtually. The aim of this symposium was to increase awareness and understanding of the impact of climate change on health for attendees. It also provided an opportunity for various health professionals to consider how to address climate change from their profession's perspective and through the lens of curriculum development and accreditation standards.

Symposium presentations comprised,

- Expert lecture: Globally recognized climate experts delivered presentations aimed at either increasing climate literacy or exploring gaps in climate-related content in curricula. Climate experts presented on the role and impact of climate change on health, and advocacy in clinical practice.
- Panel: To identify opportunities to include climate and health content, a panel comprising of faculty members from the Nursing, Occupational Therapy, Speech-Language Pathology, Medical Laboratory Sciences and Biotechnology, and Community and Trauma Counseling provided an overview of each profession's current programs and the extent to which climate change had been included into curriculum. In this process, the faculty panel identified and described each health profession's official statement on climate change and sustainability regarding inclusion of climate change in the curriculum. Faculty members included examples of how each health profession could commit to the inclusion of climate change in their respective curricula.
- Climate change competencies: Representatives from the Global Consortium on Climate and Health Education (GCCHE), housed at the Joseph L. Mailman School of Public Health at Columbia University, described their efforts to educate health professionals specifically addressing the *Climate & Health Core Concepts*. The *Core Concepts* are a highly vetted set of global educational standards that serve as a guide for HPE. This

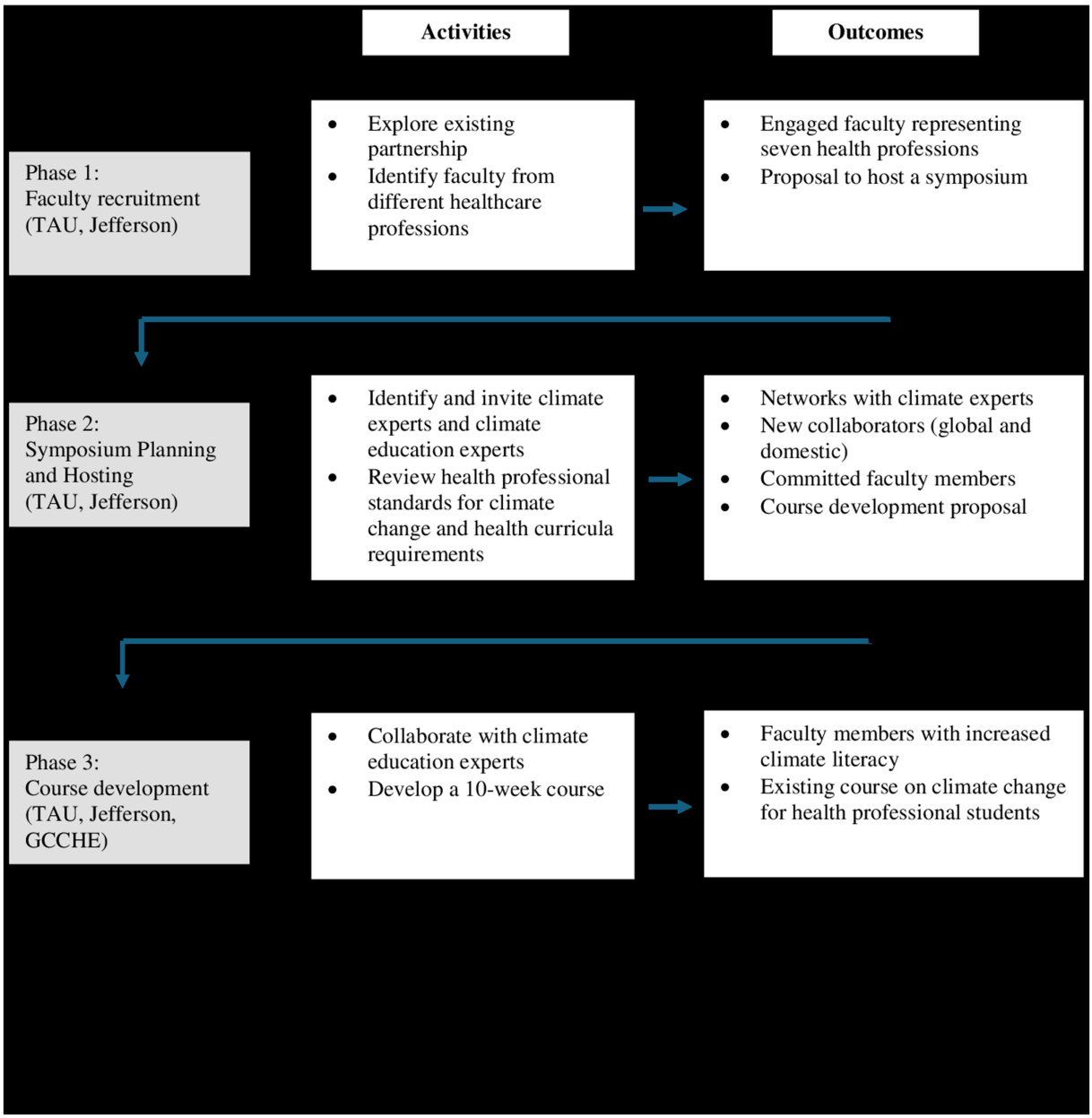

FIGURE 1
A summary of the phases, activities and outcomes for increasing climate literacy among faculty members and students in health disciplines. TAU, Tel Aviv University; Jefferson, Thomas Jefferson University; GCCHE, Global Consortium on Climate and Health Education.

document covers climate and health analytic skills and knowledge, communication and collaboration, policy, and public health as well as clinical practice competencies (17).

Feedback and outcomes: During the debrief session, faculty members acknowledged that several perceived outcomes were attained during this phase. They recognized increased knowledge on climate change and the associated health effects. In addition, they appreciated the formation of new connections with the symposium presenters, recognizing these climate experts as a resource for future potential collaboration. Finally, having recognized the dearth of climate content in health professions standards, faculty members were motivated to develop a collaborative course for graduate health professions students focusing on the respective profession's role in addressing the negative health impacts of climate change, specifically for vulnerable populations.

Phase 3: Course development

Faculty members from the GCCHE were invited to co-develop an international course for graduate health professions students, with faculty members serving as learners and facilitators.

Throughout all phases, institutional TAU and Jefferson leadership was supportive of the need to explore climate change and HPE. Both TAU and Jefferson provided funding for this research, including the educational symposium and the course. The next section will describe the course development.

Competencies and pedagogical frameworks guiding the course development

Global consortium on climate and health education competencies

The Climate & Health Core Concepts were used as guiding principles in developing this course (Box 1) (17). These concepts are a living document designed to be flexible to incorporate emerging science, yet stable to allow thoughtful curricular planning. This framework is intended as a blueprint for developing climate and health education within health professional schools as well as in continuing education programs for practicing health professionals. This framework consists of Domains (categories of educational activities), Concepts (overarching principles that form the foundation of climate and health knowledge and skills) and Learning Objectives (a brief statement that describes what students can be expected to do after successful learning relating to a concept), which can be applied and integrated as needed (17). The Climate & Health Core Concepts for Health Professionals provided the educational foundation for this course and were tailored accordingly to accommodate the requirements of the institutional partners and meet the needs of the participating international and interprofessional graduate student audience.

Transformative learning theory

Introduced by Mezirow, the Transformative Learning Theory (TLT) is a process that involves several progressive stages, starting with a disorientating dilemma where pre-existing perceptions are disrupted, followed by critical examination of assumptions, then recognition that others are experiencing a similar reckoning; it leads learners to explore options for new roles, relationships, and actions (18). TLT includes a process by which learners develop a new frame of reference in their perception of their lives and environment and affords learners freedom to explore issues "beyond the formal curriculum, such as social justice" (19).

Transformative learning can be explained as a form of metacognitive reasoning. Reasoning is the process of advancing and assessing explanations, especially those that provide points of view supporting beliefs resulting in decisions to act. Beliefs are justified when they are based on good rationale. The process of cognitive reasoning may involve such concepts as aptitudes, skills, and competencies (20). Appropriate elements of TLT, such as discourse and communicative learning, were incorporated into the course. TLT served as the guide for team reflection and evaluation of this course for the faculty members.

TLT Learning occurs as individuals engage in the process of critical reflection and analysis of their underlying assumptions. Frequently, healthcare educators function as "coaches," facilitating and guiding reflection and analysis through this critical discourse (21). This engagement and empowerment of learners results in the development of a plan for action, and the acquisition of the knowledge to implement the developed plans. Typically, learners engage in role play to gain confidence and competence to integrate the newly acquired information and skills into their personal and professional lives. By design, this interprofessional course engaged learners in group activities. This was done to facilitate new communities of learning and development of leaners' professional identities. Ong et al. explored shifts of learners' perspectives attributed to TLT as "new ideas, practices, or approaches," "new insights into existing concepts," and "new relationships [that] foster critical discourse for learning" (22).

BOX 1 The climate and health core concepts and competencies created by the Global Consortium for Climate and Health (GCCHE) (17).

- Define climate drivers (both natural and human-caused), weather, climate change, and climate variability.
- Demonstrate understanding of the scientific consensus on climate change and concept of evolving science.
- Applies fundamental knowledge of ecology, biology, and complex systems in environmental science.
- Apply knowledge of levels of prevention, climate mitigation and adaptation, and explain health co-benefits of actions.
- Describe public health and its determinants.
- Access and interpret relevant local, regional, national, and global information about climate change effects on health.
- Apply knowledge of the ethical, professional, and legal obligations relevant to climate and health.
- Identify the health impacts of climate change and effective responses on the part of specific health services.
- Apply knowledge of emergency planning skills.
- Demonstrate effective communication with stakeholders about climate and health topics.

Learning environment (setting, students, faculty members); learning objectives; pedagogical format

The learning objectives in Table 1 were modified from the GCCHE competencies to increase climate change knowledge, communication, and advocacy. The chosen objectives were designed to present the impact of climate change from an international and interprofessional perspective that includes health impacts; health policy; global and regional risks; and role identification of various stakeholders engaged in climate and health action.

The "International and Interprofessional Perspectives on the Impact of Climate Change & Climate-Related Disasters on Health and Health Care Delivery" course was delivered online over 10 weeks and included the following topics: Climate Change for the Health Professional; Extreme Weather Hazards; Climate Change and Health Equity; Food Security; Degraded Air Quality; Temperature-Related Illness and Mortality; Climate and Health Communication; and Health Sector Mitigation. Each topic was framed using the United Nations (UN) 2030 Sustainable Development Goal 13 "Climate Action." According to the UN, "Climate Action" requires "urgent action to combat climate change and its impact." Health professionals are on the front lines of mitigating the negative health impacts of climate change, and education is the first step in any change or action (23).

TABLE 1 The 10 learning objectives of the course, modified from the GCCHE competencies (17).

#	Learning outcome
1	Identify the health impacts of climate change and effective responses on the part of specific health services.
2	Apply knowledge of levels of prevention, climate adaptation, disaster responses and explain health co-benefits of climate actions.
3	Identify the risks and vulnerabilities to critical health infrastructure impacted from climate changes.
4	Use emergency planning skills to plan for and respond to climate-related extreme weather events and disasters, including workforce surge needs, and distinguish the roles of and interactions between agencies involved in emergency care.
5	Explain the role of local, regional, national and global policy frameworks and governance structures to address health risks associated with climate change and natural human disasters.
6	Apply climate and health knowledge to improve decisions about health services and impact on improving population health.
7	Access and interpret relevant local, regional, national and global information about the effects on health resulting from climate changes and disaster occurrences.
8	Apply knowledge of the ethical, professional, and legal obligations relevant to climate and health.
9	Describe the roles and responsibilities of the different health professions in preparing and responding to the climate-related health crisis.
10	Foster global cooperation and convergence on climate adaptation and mitigation.

The course involved synchronous and asynchronous learning experiences using an interprofessional healthcare approach. International experts provided synchronous lectures and learning opportunities. Both individual-level assignments and group work were included in the course. The assignments were asynchronous and included quizzes, reflection critiques, and a final examination. Two types of group assignments were included; weekly case-based problems which were completed during the synchronous sessions, and a final project that the students worked on asynchronously over the duration of the course. All assignments with grading rubrics were created and approved by the academic institutions involved in this collaboration. The GCCHE at Columbia University had previous course development expertise and recruited the speakers as part of its consultant role, so it was important for consistency that the GCCHE's Project Director grade all assignments. A survey was administered at the end of the course to capture student and faculty member feedback.

Results

Course details

Each weekly 90-min synchronous session included a 45-min lecture delivered by a climate change expert, followed by a 10-min Q&A session (Table 2). A 30-min discussion facilitated by a faculty member then followed during which students worked in groups of four to six on a climate change case study. In these peer-led groups, students collaboratively analyzed clinical scenarios, synthesized information from different sources, and were encouraged to think in new ways. An emphasis was placed on exploring different perspectives as well as on generating alternative approaches to practice challenges and emerging opportunities.

Besides the weekly group work, students were assigned to groups in which they developed a project focusing on the relationship between climate change and health outcomes. Each group chose an area of interest from the course topics and prepared a presentation responding to the prompts focusing on their selected topic. Each group presented their findings to the course participants during the last 2 weeks of the course. Students worked asynchronously for 2.5 weeks to complete the assignment.

The focus of the presentations included health professionals' responses to known health impacts of a changing climate. Students were instructed to approach the issue with an interdisciplinary and international lens, describe how different health professions can collaborate, and identify how individual health practitioners can be mobilized to respond. The prompt for the final project is shown below.

Identify a specific health issue related to a climate exposure. Through collaborative research with your peers, answer the following questions:

1. *Introduction: Why is this topic important and relevant NOW? Provide background on the specific climate related health threat.*
2. *Problem statement: What health challenges need to be addressed?*
3. *Climate attribution: How climate change and related exposure pathways are impacting the problem?*
4. *How can health professionals respond to the health impacts? What has been effective? Approach the issue with an interdisciplinary lens.*
5. *Further directions: What information or research is needed to improve our understanding of the issue to guide a successful response from health professionals globally.*

Course participant recruitment

Recruitment of TAU students involved sending emails to all students studying for a Master's degree in various health professions (Occupational Therapy, Communication Disorders, Physical Therapy, Nursing, and Emergency and Disaster Medicine). TAU faculty members also attended various classes to present the course and encourage enrolment. Recruitment of students at Jefferson involved similar processes but also included completion of an application form following advertisement. Jefferson students were enrolled from the following health professions: Physical Therapy, Nursing, Speech Language Pathology, Public Health, Occupational Therapy, and Biotechnology.

Course attendance

Faculty members who planned the symposium and developed the course also participated in the class sessions and facilitated discussions.

TABLE 2 Example of the activities and the allocated times in the 90-min synchronous sessions.

Time	Activity	Description
45 min	Lecture	Topic: Degraded Air Quality
10 min	Q & A	Students and faculty members had the opportunity to ask the speaker questions related to the lecture content.
30 min	Group work	Students were split in five groups of four to respond in discussion to the prompt below. The discussions were facilitated by a faculty member. Discussion prompt: *Your hospital's executives have asked you to give a presentation regarding air quality, health, and climate change. They have been resistant to the idea of adopting climate-smart policies in their healthcare system because they have yet to see how climate change can impact health or hospital expenses. However, after two straight weeks of terrible air quality from wildfires during the fall, they are concerned about the level of respiratory admissions which are stretching their hospital resources very thin.* *As the hospital's climate and health specialist, you are tasked with educating the executives about climate change and poor air quality and how it impacts health. Unfortunately, they gave you short notice to compile your presentation with your team. Work with your team to craft a brief presentation regarding climate change, air quality, and health.*
5 min	Wider group discussion	This time was used to succinctly share points discussed in the small group discussion with the wider group.

These faculty members selected the classes they would attend and facilitate based on their interest.

The pilot course was restricted to 30 participants. Twenty students and 10 faculty members representing seven health professions participated in this course. TAU students were in Physical Therapy ($n=5$), Occupational Therapy ($n=4$), Nursing ($n=2$), and Disaster management ($n=1$) and Jefferson students were in Physical Therapy ($n=1$), Occupational Therapy ($n=2$), Public Health ($n=4$), and Biotechnology ($n=1$). The faculty members from TAU were from the following programs Physical Therapy ($n=1$), Occupational Therapy ($n=2$), Nursing ($n=1$) and those from Jefferson were from Physical Therapy ($n=1$), Occupational Therapy ($n=1$), Nursing ($n=1$), Public Health ($n=2$) and Speech-Language Pathology ($n=1$). All faculty members were involved in all aspects of course development.

Course evaluation

Of the 20 students and 10 faculty members who participated in the course and given the same set of evaluation questions, 13 (43%) completed the survey. Based on the feedback, the speakers were highly rated with mean scores greater than 3.5/4 on the following metrics: Knowledgeable, provision of current evidence, effective delivery, appropriate tone of voice and body language, and responding to questions. Overall student and faculty members agreed that the course objectives were well connected to the learning objectives, and they valued the course as having an impact on their education and practice in terms of climate literacy (Table 3).

Discussion on the practical implications and lessons learned

As a group of 10 educators from a range of health professions, we successfully collaborated to develop a course that positioned us as learners while simultaneously training 20 health professional students from two countries. While this model for educating health professionals on climate change has not been previously described, it does align with TLT in that both faculty members and students developed an expanded interprofessional frame of reference in their perception of the impact of climate change on health. Descriptions of climate change courses for health professionals have either enrolled one discipline of health professionals (e.g., medical students only) (14), have been offered to only health professionals in practice (24), or are offered exclusively as asynchronous (15). Some of the described courses have similar elements to our course; however, none of them include faculty members and students as simultaneous learners in a course developed by faculty members and offered across two institutions. While Rom (16) developed a course that has now been offered at three institutions sequentially, our course can be offered at multiple institutions simultaneously.

Through this course development and deployment, faculty members gained knowledge in climate change and health while simultaneously educating health professional students. This example of student and faculty member co-learning can serve as a model to rapidly deploy HPE in response to emerging health crises, including the climate crisis and the remaining triple planetary crises of biodiversity loss and pollution.

Lessons learned

Climate change expertise not required

Climate change *expertise* is not a pre-requisite for developing a course that is impactful. None of the educators who collaborated on this course was a climate expert. Notwithstanding, they successfully invited expert guest lecturers and facilitated learning through guided discussions. Each faculty member was sensitive to climate change impacts and therefore open to collaborating and learning. It is therefore important to strategically identify such faculty members who will remain committed to the process of educating themselves and others through course development and delivery. Our results suggest that climate change novices can creatively design courses for students even though they currently do not possess the appropriate knowledge. As suggested by Shaw et al., the climate crisis calls for change in how education is approached (25). Faculty members who are experts at sharing wisdom with learners in their own specific fields need to stand side by side with their colleagues and their students to create space to learn and collectively respond to crises.

Institutional collaboration is key

Collaboration through existing or novel partnerships was instrumental to the success of this course. In this case, an existing partnership between the two institutions provided the foundation for

TABLE 3 Student and faculty members' feedback on course format, content, and delivery.

Feedback categories	Response summary and selected quotes
Course format and delivery	Weekly didactic lectures followed with group activities and discussions was positively noted as a good format. Generally, the expert lectures were found to be engaging and interesting. The virtual format of the course was appreciated as students could review the video recordings asynchronously at their own pace. • "Most of the lecturers were good and very interesting." • "It was online and recorded (I did join in most classes but could review them again and make up for the ones I could not attend)" • "Weekly group activities and discussions with students and faculty."
International perspective	Interactions with international students were highly valued, offering diverse perspectives, insights into different social support systems and discussion of each country's unique climate change response. • "The final group project allowed for interprofessional and international collaboration to explore and present on a specific climate change topic impacting health." However, some respondents noted that there was insufficient information on the impact of climate change on health in various countries. • "The guest speakers could have benefitted from including more data and information about the impact of the various climate change topics on health in Israel and other countries other than the U.S., especially those vulnerable and/or developing."
Interprofessional collaboration	Respondents generally reported an appreciation for the interprofessional collaboration opportunities provided by the course. Students enjoyed engaging with individuals outside their field of study through discussion and group work. • "Being able to talk and engage with those outside of my field of study."
Guest speakers' presentation focus	It was suggested that an emphasis was needed on implementable healthcare action steps related to climate change. • "... more of their (speakers) allocated time to present could have been dedicated to implementable healthcare action steps and our role in combatting the discussed climate change topics."
Pace and content of some speakers	The respondents expressed desire for more direct connection to specific professional roles and actionable steps related to each climate and health topic. It was noted that some presented spoke too quickly for an international audience to follow the content. Some individuals remarked on the unequal distribution of assignment responsibilities, particularly noting disparities between students enrolled for credit and those voluntarily participating. • "Most speakers were fine. Some talked too fast. Most talk more about the problems and less about solutions."

collaboration. The current impact of climate change on health and the environment has potentially generated concern among several faculty members to think about it. An invitation to partner on a collaborative course development can be the motivator for faculty members to contribute to climate change course development.

The symposium and the course provided faculty members with additional networking opportunities with climate experts who presented at the symposium or delivered the lectures. Moreover, the materials they presented or shared become resources that faculty members and students could utilize to develop climate literacy. Further, in the learning process, student collaborations led to an enriched learning experience for the students.

Faculty members and students can learn simultaneously

In our course, faculty members and students were simultaneously enrolled as learners in the course. All learners attended the course content delivered by the climate experts. The discussion sessions allowed for learning from one another. However, the faculty members did not have to complete any of the assignments. Faculty members increased their climate proficiency, equipping them to then develop more institution-specific climate change courses. Students were able to observe their faculty members as learners and were exposed to different, and possibly more advanced, learning and knowledge processing styles.

Diversity enhances learning

The climate experts who presented at the symposium and during the course originated from a range of professions, institutions, and countries, allowing learners to gain different location-and profession-specific perspectives, thereby enriching the learning. Climate change is a universal experience, and global co-operative learning can provide faculty members and students the opportunity to understand more realistically how their actions impact others, learn about different mitigation and adaptation strategies, and collectively develop solutions. The course participants (faculty members and students) who were also diverse represented various health professions from two institutions.

Pragmatic considerations when developing international coursework

Institutional differences

Collaborating faculty members may need to review university-level curricula development guidelines and their respective curriculum committee guidelines as this can direct the course development process. In our case, one institution was unable to offer the course to its students as a credit-bearing course due to the institution structure, specification, and time required to approve new courses. Furthermore, student recruitment may be specific to the respective institutional guidelines.

Another barrier was that the two institutions used different education platforms for course content management. To overcome this, a common location was created. Interested faculty members might want to check their institution-specific guidelines about shared document management software.

Notwithstanding, such institutional bureaucracies should not dampen collaborative efforts to develop inter-institutional climate change courses. In fact, offering this course simultaneously as a credit course at one institution and as non-credit at the other institution demonstrates flexibility of the course design.

Logistics

Working internationally presents several logistical considerations. A logistical challenge was the six-hour time difference that provided a narrow window of time during which the course could be offered. Faculty members at other institutions who might want to adopt this model may need to be creative in terms of timing and/or format of course delivery to accommodate time differences. Despite this logistical challenge, the successful launch and delivery of the course demonstrated the ability to synchronously offer an international online course with learners from different places.

Pedagogical considerations

Because of the predicted diverse groups of health professions students anticipated to enroll in the course, we chose to utilize a co-operative learning format. The small groups were deliberately diverse with respect to profession and country of residence, but also in terms of race and academic background. Furthermore, we chose group work because it is associated with more active learning; knowledge development, which include critical thinking, time management and leadership, refined idea articulation, as well as a knowledge of the topic. The ability to have critical discussions in small groups is an important part of transformative learning (21, 26). Small groups require participants to share their thoughts and opinions, which is an important part of the learning process. In small groups, students cannot remain passive, and by being part of the conversation, they are encouraged to critically examine and interact with the ideas being presented, increasing the chance of broadening and deepening their understanding.

Reflections and next steps

Based on the student and faculty members' feedback, we plan to further develop the course to offer additional content on Policy, Public Health Practice, and Clinical Practice. This correlates with the imperative that healthcare practitioners need sufficient foundational knowledge to understand the detrimental effects of climate change on health as well as the need for interprofessional collaboration among stakeholders to improve health outcomes. Most participants had not made a connection between understanding what climate change is and connecting it to poor health outcomes. For example, there are increased incidences of heat waves and floods (2), but participants may not make the connection. Therefore, future iterations of this course will expand the scope, including the importance of health professionals understanding how health policies may improve or exacerbate health impacts. In addition, future iterations will also integrate the impact of public health practices in addressing the impacts of climate change from a prevention perspective. Examples include developing effective public health warnings about how to stay cool during heat waves, and strategies to mitigate emission in the health sector.

Furthermore, we deliberated upon two next steps: initially, to extend the offering of the developed curriculum in its current state with newly forged global partnerships, or as an in-person, week-long academic exchange within a carefully chosen venue. This iteration of the course would incorporate the existing recorded lectures as well as enlist identified speakers to record lectures for dissemination among the students. These pre-recorded lectures can then be accessed asynchronously, allowing for increased engagement in active learning pertaining to the role of health professionals within relevant contexts. Additionally, experiential learning will encompass visits to healthcare facilities, facilitating an understanding of the respective challenges in healthcare delivery within the framework of climate change.

Secondly, aiming to furnish a blueprint or offer ideas for individuals who are motivated to run similar courses but lack exposure to the development of such curricula, we have explored the prospect of organizing and hosting an international conference. We would extend invitations to individuals to share their experiences—both the opportunities and challenges—related to the development of climate change curriculum tailored for health professionals. Additionally, we envisage that this conference will attract a gamut of health professionals who may or may not have encountered climate change content yet within their educational curriculum. Furthermore, we anticipate the attendance of representatives from various organizations encompassing healthcare, public health, and related sectors, who have implemented strategies promoting climate change awareness, education, and advocacy specifically targeted at health professionals.

Conclusion

This three-phase process to develop and then run a climate change pilot course by interprofessional faculty members from two institutions simultaneously increased climate literacy for faculty members and students. The course was built on the foundational competencies already established by the GCCHE and the collaboration provided access to climate change expertise and resources. The success of each phase (faculty member recruitment, symposium planning and hosting, and course development) was a result of collaboration, creativity, commitment and communication. The steps leading up to and including the developed course can be used as a model by climate novices to develop an international interprofessional collaborative climate change course for health professions education.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The requirement of ethical approval was waived by the Office of Human Research-Institutional Review Boards at Thomas Jefferson University and Tel Aviv University for the studies involving humans because the course evaluation data did not include personal health information (PHI) or other identifiable data. Learners were asked only to evaluate the course and reflect on their experience in the class. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation

was not required from the participants because the data collected was course evaluations at the end of course delivery.

Author contributions

HO: Writing – original draft, Writing – review & editing. PAR: Conceptualization, Writing – original draft, Writing – review & editing. AF: Writing – original draft, Writing – review & editing. HC: Writing – original draft, Writing – review & editing. SB: Conceptualization, Writing – original draft, Writing – review & editing. JF: Writing – original draft, Writing – review & editing. SBK: Writing – original draft, Writing – review & editing. RF: Writing – original draft, Writing – review & editing. CS: Writing – original draft, Writing – review & editing. TB-S: Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing. LNH: Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing.

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EDITED BY
Jacqueline G. Bloomfield,
The University of Sydney, Australia

REVIEWED BY
Gustavo J. Nagy,
Universidad de la República, Uruguay
Paulo Hilario Nascimento Saldiva,
University of São Paulo, Brazil

*CORRESPONDENCE
Carmen Jochem
✉ carmen.jochem@uni-bayreuth.de

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Planetary health literacy as an educational goal contributing to healthy living on a healthy planet

Carmen Jochem[1]*, Julia von Sommoggy[2], Anna-Katharina Hornidge[3,4], Eva-Maria Schwienhorst-Stich[5] and Christian Apfelbacher[2,6]

[1]Department of Planetary & Public Health, Faculty of Law, Business & Economics, University of Bayreuth, Bayreuth, Germany, [2]Institute of Social Medicine and Health Systems Research, Otto-von-Guericke University Magdeburg, Magdeburg, Germany, [3]German Institute of Development and Sustainability, Bonn, Germany, [4]Department for Political Sciences and Sociology, University of Bonn, Bonn, Germany, [5]Department of General Practice, Working Group Climate and Planetary Health, University Hospital Würzburg, Würzburg, Germany, [6]Nanyang Technological University Singapore, Lee Kong Chian School of Medicine Clinical Sciences Building, Singapore, Singapore

KEYWORDS

planetary health literacy, education, planetary health, sustainable development, health professionals

1 Introduction

Education plays a key role for sustainability, and thus for healthy living on a healthy planet (1, 2). In particular, education for sustainable development (ESD) and planetary health education (PHE) can unfold their transformative potential for sustainable planetary health through the provision of information and passing on of knowledge, attitudes and skills relating to the interconnection between sustainable development, environment and human health (1). Within ESD and PHE, enabling individuals to develop competencies and practical skillsets to make decision that are environmentally sensitive and health promoting could be a key educational goal.

2 Toward planetary health literacy

However, existing literacy concepts that aim to improve such competencies mostly remain within their inherent perspectives and disciplines. Whereas health literacy exclusively refers to human health, environmental literacy refers to wellbeing in a broader context than specifically to individual human health (3, 4). In ESD and PHE, sustainability and transformative literacy are the concepts predominantly used. Although these concepts include crucial aspects for sustainable development and transformative change, they do not explicitly address environmental and human health aspects. Thus, the strong interconnection between human health and the environment—in the sense of planetary health—is not reflected adequately by existing literacy concepts.

Considering the lack of a comprehensive and integrative literacy concept that includes all relevant aspects, we proposed a conceptual model of planetary health literacy (PHL) (5), defining PHL as "the knowledge and competencies of accessing, understanding, appraising, and applying information in order to make judgements and take decisions regarding planetary health, across societies and for health-promoting, sustainable, and transformative actions. Planetary health literate individuals and societies are enabled to sustain and promote their own health, population health, and the

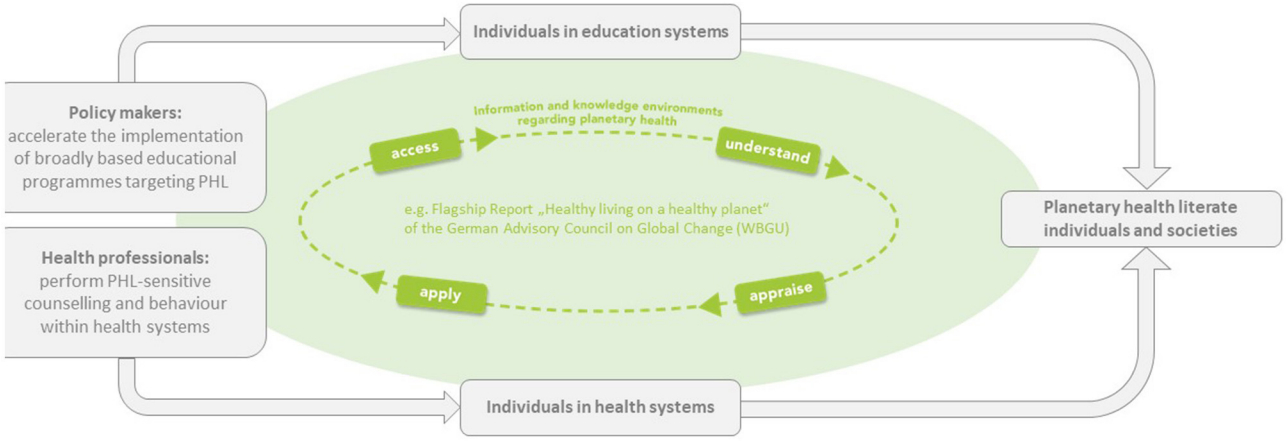

FIGURE 1
Role of PHL for the vision of healthy living on a healthy planet. Policy makers and health professionals (among others) can serve as relevant multipliers of PHL within the education and health system. Their knowledge and competencies enable them to behave in a planetary health literate way, i.e., to access, understand, appraise, and apply information and knowledge environments regarding planetary health—such as the recommendations for "Healthy living on a healthy planet" by the German Advisory Council on Global Change. Implementing these recommendations would contribute to learning and knowledge environments that help individuals—within the education system and the health system—to develop PHL and to make decisions for health promoting and sustainable lifestyles.

planet's health. They are able to adopt a more holistic understanding of their health embedded in natural systems they are living in. Based on their knowledge and attitude, they take decisions that reflect and foster the interconnectedness of human health and wellbeing with the state of the natural systems and related areas of nature-society interactions" (5). By encompassing both a life-course and transgenerational approach, PHL may act across multiple current and future generations. Thereby, PHL goes beyond the individual level and includes a societal and global level.

3 Planetary health literacy as an educational goal

Education fostering PHL could enable individuals and societies to positively contribute to the vision of healthy living on a healthy planet and to the associated transformation to sustainability (1). To achieve this vision, the German Advisory Council on Global Change—an independent scientific advisory body of the German government—recommends political actors to systematically promote education for healthy living on a healthy planet worldwide (1). Using PHL as goal in an education strategy should "enable and promote knowledge, attitudes and skills relating to environmental and human health throughout life, and [...] encourage sustainable action within the educational institutions themselves" (1). The existing processes of embedding ESD in all areas of education—from pre-school to advanced-training programmes—and of implementing PHE not only in health-related educational programmes, should be reinforced and policy makers should accelerate the implementation of new broadly based educational strategies targeting PHL as soon as possible (1). Health professionals would contribute to environmentally sensitive health promotion and prevention through PHL-sensitive counseling [e.g., climate-sensitive health counseling (6)] and to sustainable health systems through sustainable behavior and use of resources. Within these information and knowledge environments, individuals, and societies could become planetary health literate and, for example, make more health promoting and sustainable decisions regarding nutrition or mobility. Figure 1 illustrates the role of PHL for the vision of healthy living on a healthy planet.

4 Discussion and research needs

Such a vision does not only require political and societal action, but is accompanied by several research needs: First, PHL itself needs to be investigated in more detail. The conceptual model needs to be empirically validated and a set of indicators need to be determined to assess PHL. Second, inter- and transdisciplinary research projects that investigate in a participatory manner how educational programmes can be developed and implemented to enable PHL across the life-course are needed [e.g., in real-world laboratories (7)]. Third, the implications of different ways of knowing, power dynamics, justice and equity on planetary health literacy need to be understood.

In conclusion, the prompt implementation of recommendations—not only related to education—of scientific advisory bodies such as the global urgency governance emphasized by the German Advisory Council on Global Change are crucial for healthy living on a healthy planet. The concept of planetary health literacy can serve as an educational goal contributing to this vision.

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Publisher's note

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EDITED BY
Ciraj Ali Mohammed,
National University of Science and Technology, Oman

REVIEWED BY
Gustavo J. Nagy,
Universidad de la República, Uruguay
Arindam Mitra,
Adamas University, India

*CORRESPONDENCE
Catarina Pais Rodrigues
✉ cpaisrodrigues@gmail.com

†These authors have contributed equally to this work

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Development of a suite of short planetary health learning resources by students for students as future health professionals

Catarina Pais Rodrigues[1,2*†], Evangelos Papageorgiou[2,3†] and Michelle McLean[4†]

[1]National School of Public Health, Lisbon, Portugal, [2]Medical Student Alliance for Global Education (MeSAGE)-ScholarRx, Louisville, KY, United States, [3]Evangelismos Hospital, Athens, Greece, [4]Faculty of Health Sciences and Medicine, Bond University, Gold Coast, QLD, Australia

Planetary health recognizes the interdependencies between human health and the well-being of the Earth's ecosystems. Human activities have led to the disruption and transformation of natural systems and a range of global environmental changes such as climate change, air pollution, and biodiversity loss. Health professionals must be equipped to deal with the health impacts of global environmental changes. This article describes the development and usage of a suite of 14 short online learning resources ('bricks') on Planetary Health on the ScholarRx platform. There are several principles that inform the development of these bricks, including learner-centric, peer learning, diversity, equity and inclusion, and authentic learning. The content is developed using a student-educator collaboration model, supported by an editorial team. The suite of 14 modules was published in June 2023, with the initial usage data promising with 1,990 views in the first 10 months. These digital, modular resources allow for easy dissemination and can be incorporated in different programs depending on context and need.

KEYWORDS

health professions education, planetary health, meaningful student involvement, open education, sustainable health education

1 Introduction

In 2009, Costello and colleagues identified climate change as potentially the greatest threat to global health in the 21st century, concluding that this *"raises many challenging and urgent questions for politicians, civil servants, academics, health professionals, NGOs, pressure groups and local communities"* (p. 1728) (1). Despite extensive deliberation, meetings, and conferences, inaction combined with a growing human population, resource extraction, fossil fuel burning, deforestation and pollution have led to the transformation and disruption of many of Earth's systems. The planet's inhabitants now face a triple planetary crisis: A changing climate, biodiversity loss, and pollution (2).

Health and well-being are inextricably linked to the health of the planet. Changing land and sea temperatures have led to droughts, storms, floods, heatwaves, and rising sea levels, resulting in the loss of human life and property (3). These same weather patterns are also

having devastating impacts on plants and animals, displacing many species, disrupting breeding cycles, and causing death (4). It is not surprising that in late 2023, health journal editors declared that it was time to consider the climate and nature crises as one urgent global health emergency (5). Our natural environment, which provides us with our basic needs of air, food, and water, as well as a range of other 'services,' is now the foremost determinant of our health. Air pollution is responsible for 9 million premature deaths annually (6), with increasing evidence of links to other conditions such as Alzheimer's disease (7). The millions of tonnes of plastics that pollute every ecosystem, including the deepest oceans, have introduced micro- and nano-plastics (MNPs) throughout our food chains (8). These MNPs are recognized as endocrine disruptors and carcinogens, as are the 'forever' chemicals, per- and poly-fluoroalkyl substances (PFAS) (9).

Health professionals must be equipped to deal with the impacts of the triple planetary crisis on patients, communities, and the health system. Increasingly, health professionals are being called on to advocates for vulnerable populations—such as children, pregnant women, and the elderly—as well as for the planet (10). Health professions education (HPE) has, however, been slow to include concepts such as environmental and ecological determinants of health, environmentally sustainable healthcare, and climate and ecological justice in curricula. A 2020 International Federation of Medical Students' Associations (IFMSA) survey of 2,817 medical schools in 112 countries among found that only 15% had included climate change and health in the curriculum, and only 11% had included air pollution and health (11). It is not surprising therefore that some medical students have become educational activists, working to ensure that they are prepared for a just and sustainable future for all (12–14).

While initial calls to action in HPE focused on sustainable healthcare to reduce carbon emissions and mitigate climate change (15, 16), there is now a growing recognition of the need for a more holistic approach that includes the health of the planet. Early efforts included incorporating 'sustainability' into the UK's Graduate Outcomes Statements (e.g., GMC Good Doctor 2018) and addressing the impacts of climate change (12). However, this focus on carbon emissions is increasingly seen as too narrow. A broader perspective that considers issues such as resource scarcity, overconsumption, ecotoxicity, and biodiversity loss is essential (17). The Planetary Health Alliance's Planetary Health Educational Framework, which centres the connection with Nature (18), and the Association for Medical Education in Europe's 2021 Consensus Statement for Planetary Health and Education for Sustainable Healthcare (19)—which outlined the knowledge, skills, values, and attributes for future health professionals—were forerunners in advocating for the integration of Planetary Health in health professions education. Additionally, McKimm and McLean's (20) article on eco-ethical leadership outlined what was needed to shift the paradigm in health professions education.

Calls for and action toward the integration of Planetary Health in health professions education are gaining momentum (21). While much of this integration has occurred at the subject (22) or program level (23, 24), other institutions have adopted these changes at the faculty or university level (25). At least one country, Australia, now has accreditation standards that include outcomes relating to climate change, sustainable development, environmental determinants of health, Planetary Health, and sustainability (26).

This article describes the development and usage of a suite of 14 Planetary Health learning resources created by the Medical Student Alliance for Global Education (MeSAGE), an initiative supported by ScholarRx. ScholarRx is a digital education platform with a vision to create a shared global curriculum system, enabling learners, educators, and institutions to create curriculum components (27). These learning resources, called 'bricks', comprise short, individual digital learning topics featuring narrative text and interactive multimedia that students can complete in 15 to 20 min. MeSAGE is an alliance of 11 international student organizations that is developing open educational resources, in the form of bricks, on topics that student organizations have been advocating for and deem relevant for HPE (28). Topics are prioritized based on a needs assessment completed by representatives of international student organizations. MeSAGE has published content on different topics such as Sexual and Reproductive Health and Rights, Digital Health and, in this case, Planetary Health.

Initially, the needs assessment identified climate change as the primary topic. After consultation with experts in 2022, it was acknowledged that climate change was only one of several global environmental changes that needed to be included in the medical curriculum. A Planetary Health lens was deemed more appropriate to address the broader range of environmental issues impacting health and well-being.

2 Pedagogical framework(s) pedagogical principles, competencies/ standards underlying the educational activity

MeSAGE's endeavors to develop educational resources for students, by students. Several principles inform the development of these resources namely learner-centric, peer learning, diversity, equity and inclusion. These bricks provide students and educators with just-in-time and just-for-you learning resources.

2.1 Learner-centric, peer learning

Collections of bricks are developed by students based on students' perceived needs, thereby ensuring that the concepts and content are current and relevant. As student authors are recruited from across the world, the bricks capture the global student voice, ensuring that the content reflects global issues. Guided by an expert, students define the learning objectives and determine the content of the bricks. This approach promotes the learning of ideas and concepts through informal discussion, cognitive restructuring, and activation of knowledge (29).

2.2 Diversity, equity and inclusion (DEI)

MeSAGE aspires to cultivate diversity and inclusion in HPE. Content is developed by students from different regions of the world, in the case of the Planetary Health suite, students from 11 countries (Canada, Egypt, Greece, Honduras, India, Lebanon, Mexico, Nepal, Nigeria, Serbia, and the United States) contributed to the bricks. Additionally, a concerted effort is made to challenge

assumptions about different countries and vulnerable populations by sharing examples from various regions of the world and discussing issues and contributions of specific populations. The scenario presented at the start of each brick and examples provided in the narrative reflect relevant global realities (e.g., a person moved from a rural village to a city and experienced an asthma exacerbation presumably from air pollution), or in instances when it is important to identify a specific region or country, the brick usually includes a perspective from a high-income country and a low-income country (e.g., wildfires in Australia and flooding in Pakistan). Furthermore, in specific bricks such as the *Introduction to Planetary Health* and the *Environmental Justice* brick, the contributions of industrialized nations to ecosystem disruption and the vulnerabilities of Global South countries and frontline states are discussed, highlighting how low-income communities and Indigenous populations are disproportionately affected by global environmental changes. All content is written using person-centered language, following the American Medical Association guide (30).

2.3 Brick format: a template for authentic learning

As has been described, content is delivered in the form of bricks, which are digital learning resources featuring narrative text and interactive multimedia with self-assessment items (31). These bricks follow an instructional design template designed according to well-established educational theories and practices:

2.3.1 Just-in-time, just-for-you

Two of the principles identified for effective continuing medical education are convenience (just-in-time) and individualization (just-for-you) (32). Bricks allow for that convenience as they are easily accessible online are short, concise resources that should take the learner 15–20 min to complete. The bricks format also allow for learner customization, as they can choose the order in which they engage with the bricks, depending on their individual needs. As student authors, who are not experts on the subject, develop the content the bricks will also reflect the unique perspective of the target audience.

2.3.2 Andragogy

Andragogy, or adult learning theory, is often introduced in juxtaposition to pedagogy, which focuses on how children learn. It emphasizes that adult learning is self-directed, relevant, and centered around a task or problem (33). Thus, each brick starts by clearly stating the learning objectives and introducing a scenario, referred to as a 'case connection', that the learner revisits and resolves by the end of the brick. Each brick is a discrete learning experience, allowing the learner to choose their learning pathway, whether following the sequence presented or based on their own needs or curiosity. The reference list at the end of each brick includes the most relevant publications for further reading.

2.3.3 Relevance and application of knowledge

The 'case connection' that starts and concludes each brick depicts a real-life scenario that a HPE student might encounter, highlighting the relevance of the content for the learner. In the Planetary Health suite, these 'case connections' cover global experiences of the planetary crisis, from flooding to wildfires. The use of a real-life scenario promotes authentic learning, ensuring knowledge covered in the brick is transferable to real-world practice (34).

2.3.4 Learning by chunking, plus a Socratic approach

Each brick is divided into sections (chunks of information). Each section begins with a question and covers a specific learning objective. The goal is to set a pace, walking learners through the content and prompting them to engage and reflect on the question posed in the heading of each section.

2.3.5 Multimedia learning

Recognizing that individuals learn best through a combination of words and pictures, each brick has a minimum of two images that highlight essential material, and which are integrated in the text (35).

2.3.6 Continuous assessment, with feedback

Each brick includes interactive self-assessment items after sections or paragraphs for students to evaluate their understanding of the learning objectives (36). These self-assessment items include flash cards with open-ended and short-answer questions while engaging with the brick content, plus 4–5 multiple-choice, single-best answer questions at the end. Learners can only access the answers after engaging with the interactive elements, ensuring active participation and reflection.

2.4 Meaningful student engagement in the development of peer learning resources

A foundational principle of MeSAGE is meaningful student engagement in the development of educational resources through student-educator collaboration (28). The ScholarRx editorial team comprising a project manager, a curriculum manager, developmental editors and illustrators supports this collaboration, liasoning with students and the educator, editing content for clarity and consistency across modules, and creating artwork for the content. Figure 1 provides an overview of the workflow in developing a suite of bricks.

In the initial phase of a themed suite of bricks, students with advocacy experience in the area under consideration, such as Planetary Health, propose an outline, in which the bricks, learning objectives and content to cover to meet learners' needs are identified. This outline is reviewed by the educator, an academic with expertise in the field, and finalized after asynchronous feedback between the students and the educator. ScholarRx's curriculum manager reviews the outline to ensure the learning objectives and content organization suit the brick format. In the case of the Planetary Health suite, the feedback rounds during the outlining phase broadened the scope of the resources from seven bricks on climate change and health to 14 bricks on various Planetary Health topics, including air pollution, extreme weather events, and environmental justice.

Once the suite outline has been finalized, student authors are assigned to individual bricks, based on their stated preferences. Students apply to be authors via an online application form in which they share their academic information, such as graduation year, experience in research or medical writing, as well as their interest or

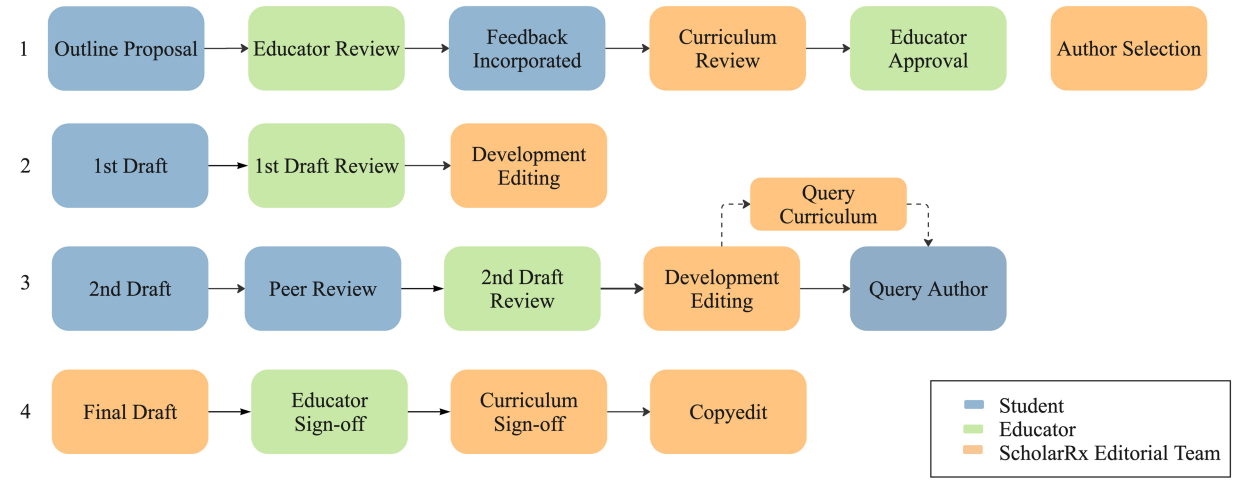

FIGURE 1
Bricks workflow.

experience in medical education. From these applicants, those with educational experience, such as leading peer-tutoring groups, are invited to write a section of the brick covering a specific learning objective. These assignments are reviewed and scored by two ScholarRx editorial team members, who evaluate the content quality and writing clarity. The candidates with the highest scores are then selected to develop the brick.

Each brick underwent three draft phases in which was reviewed by the educator and the developmental editor. At the second draft stage, the authors conduct a review on a different brick than the one they had developed (peer reviewer). The developmental editor may query the curriculum manager at this stage to resolve any issues related to the content organization or the pedagogical approach. At the final draft stage, artwork is developed according to the students' instructions and placed in the bricks. The educator and curriculum manager signoff on the content before it is published.

3 Learning environment (setting, students, faculty); learning objectives; pedagogical format

The Planetary Health suite of 14 bricks aims to provide foundational knowledge on the topic, enabling future health professionals to recognize the environment as a determinant of health, identify the health impacts of a changing climate, biodiversity loss, and pollution, and advocate for strategies to reduce these impacts, such as practicing sustainable healthcare (Table 1):

- Introduction to Planetary Health
- Air Pollution
- Water Quality
- Climate Change and Health
- Extreme Heat
- Severe Weather Events
- Vector Ecology and Zoonoses
- Food and Water Security
- Mental Health and the Environment
- Climate Migration and Displacement
- Climate-Related Disaster Preparedness
- Climate Mitigation and Adaptation
- Environmental Justice
- Health Systems and the Environment

The primary aim of the Planetary Health suite was to provide resources that can be used in their entirety by students and educators in the curriculum or as standalone learning resources that can be integrated into individual curriculum sessions. These bricks can be used as a self-directed learning resource, a pre-reading assignment before a face-to-face session, or integrated into a synchronous learning activity. The platform hosting the bricks currently collects data on the usage but does not evaluate or award a certificate for completion.

4 Results to date/assessment (processes and tools; data planned or already gathered)

The bricks were published in June 2023. In the first 10 months after publication, the resources were viewed a total of 1,990 times, with *Introduction to Planetary Health*, *Air Pollution, Extreme Heat*, and *Vector Ecology and Zoonoses* garnering the most attention (Figure 2).

Following the release of the Planetary Health bricks on the ScholarRx platform, a webinar was held in October 2023 to introduce the Planetary Health suite to educators. The webinar was conducted as an interview, with the Curriculum Manager for the PH suite (CPR, author), posing key questions to the Planetary Health suite content expert (MM, author). An invitation for the webinar was sent to everyone on ScholarRx's mailing list. Of the 78 registrants, 17 attended, with six providing feedback that included: "I hope to use them to educate peer educators," "I have never used them before, but I am going to incorporate these in my curriculum now," and "Fantastic guide for how to advocate for its implementation in vet[inerary] curricula." All registrants received a link to the recording.

TABLE 1 The 14 Planetary Health bricks and the associated learning objectives.

Brick title	Learning objectives
Introduction to Planetary Health	Define planetary health and global environmental changes. Explain why the environment is a determinant of health. Identify planetary boundaries that are being exceeded. Explain the concept of sustainable development and doughnut economics.
Air Pollution	Define air pollution. Distinguish sources of air pollution. Describe the health effects associated with air pollution. Explain strategies to minimize the health effects of air pollution.
Water Quality	Define water quality, including the various harmful contaminants of fresh water. Explain the importance of clean water for human health. Identify the health effects of poor-quality water. Explain how to minimize the health effects of poor-quality water.
Climate Change and Health	Describe the dynamic interaction of elements in the climate system. Explain how human actions contribute to a changing climate. Identify climate-sensitive health risks. Define climate-resilient health systems.
Extreme Heat	Define extreme heat. Explain how extreme heat events are affecting health. Describe the clinical presentations associated with extreme heat. Discuss strategies to minimize the health effects of extreme heat.
Severe Weather Events	Distinguish types of severe weather events. Explain why severe weather events are increasing in frequency and intensity. Explain how natural disasters impact health. Explain how to minimize the health effects of severe weather.
Vector Ecology and Zoonoses	Define vector ecology and zoonoses. Explain the relationships between environment, host, and infectious agent. Identify climatic factors that contribute to infectious diseases. Explain the link between a changing climate and the increase in vectors and infectious diseases. Identify public health strategies to mitigate environmental risks for infectious diseases.
Food and Water Security	Define food and water security, including the state of food and water security worldwide. Explain how global environmental changes impact food and water security. List strategies to build climate-resilient food systems.
Mental Health and the Environment	Describe the relationship between mental health and the environment. Explain how environmental degradation impacts mental health. Identify strategies to address the impact of the planetary crisis on mental health.
Climate Migration and Displacement	Distinguish between the concepts of migration and displacement. Explain how environmental changes can lead to displacement. Identify the impact of climate migration and displacement on populations' health. Recognize the importance of health interventions in the context of climate migration and displacement.
Climate-related Disaster Preparedness	Define climate-related disaster preparedness. Explain the impact of climate-related disasters on health and emergency care. List strategies to prepare for health emergencies during climate-related disasters. Explain the steps in the disaster management cycle.
Climate Mitigation and Adaptation	Define climate mitigation and adaptation. Define health co-benefits of climate mitigation and adaptation. Identify public health interventions promoting climate mitigation and adaptation. Explain climate resilience and ecosystem restoration
Environmental Justice	Define environmental justice. Explain why global environmental changes have a disproportionate impact on different regions. Identify the population groups most vulnerable to the impacts of global environmental changes. Explain strategies to reduce the impact of environmental changes.
Health Systems and the Environment	Describe the relationship between health systems and the environment. Describe the components of climate-resilient health systems. Explain the impacts of health systems on the environment. List strategies to promote environmentally sustainable health systems. Explain the role of health professions in promoting environmentally sustainable health systems.

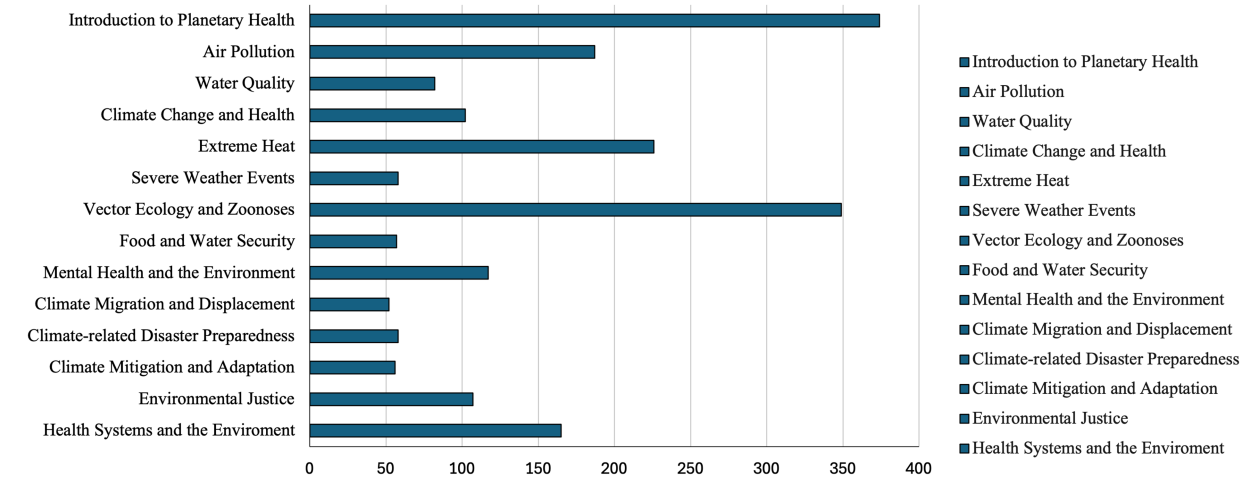

FIGURE 2
Number of brick views in the first 10 months after publication.

In 2023, MeSAGE ran two social media campaigns on Instagram promoting the Planetary Health suite. The content reached over 45,000 people, generated 2,000 interactions, and led more than 750 people exploring the collection.

During 2024, two online sessions were arranged to introduce students to the topic of Planetary Health and the suite of bricks. A session titled *"Advancing Planetary Health through Open Education"* was held during Open Education week in March 2024, and another session was held during the IFMSA's European Regional Meeting in April 2024. The Planetary Health Bricks have also been added to OER Commons, a library of open educational resources.

MeSAGE plans to continue these implementation efforts by tracking usage data, delivering a set of synchronous peer-to-peer sessions based on bricks in the second half of 2024, and collecting direct feedback from educators on factors that support or hinder implementation.

5 Discussion on the practical implications, objectives, and lessons learned

There is an increasing call for HPE to include Planetary Health in the curriculum to ensure that graduates are prepared to practice sustainable healthcare and to be advocates for a cleaner, greener future for all. Health professions eeducators, who are often time-poor and may also not be Planetary Health experts, now have access to free open educational resources on which to draw. ScholarRx's Planetary Health bricks offer educators free just-in-time and just-for-me resources that have been developed for students, by students and reviewed by an expert.

As a digital, open education resources published under a Creative Commons license, bricks can be shared freely allowing for easy dissemination and potential adoption by HPE education institutions worldwide. The digital format also allows for quicker updates and revisions, ensuring that the material remains current with the latest research and developments in Planetary Health. Due to its modularity and customizability, bricks can be easily incorporated in different programs and educators can tailor the content, depending on the context and learners' needs.

While initial usage data is promising, a deeper understanding of the bricks effectiveness in meeting Planetary Health learning outcomes is required. Assessing the impact on student learning will be difficult, given the likely global usage of these resources. Surveys and focus groups with students and educators can provide information on the perceived learning gains, strengths and potential areas of improvement. There may also be opportunities for collaborations with educators who incorporate or integrate the bricks in their courses, so they can conduct pre- and post-assessment of learning objectives or track students' learning and application of knowledge as it pertains to the topic of Planetary Health.

It is also important to note that developing innovative educational resources is an iterative process. As the resources are used, we aim to gather perspectives on potential improvements. A few weeks before the submission of this article, the platform upgraded its feedback features to prompt the users to share their perception of the learning experience. At the end of the brick, the users will see to buttons "thumbs up" and "thumbs down" and when they click on either, they can justify the feedback by selecting from a set of options (e.g., "clear and understandable," "current and relevant information," "difficult to understand," "questionable or unreliable content") or writing a comment. The expectation is that this data will inform subsequent revisions and updates to the content. New bricks addressing other aspects of Planetary Health should also be considered such as the health impacts MHPs and 'forever' chemicals, and biodiversity loss.

Finally, despite the merits of the current development process in terms of meaningful student engagement, there may be opportunities to further empower students. First, the student-educator collaboration can be strengthened by promoting synchronous sessions for alignment and feedback. Secondly, students can be encouraged to develop an activity to support the implementation of the brick they authored or the suite of bricks, which would encourage them to be educational activists and actively engage in their own education.

6 Acknowledgment of any conceptual, methodological, environmental, or material constraints

The topic of Planetary Health has not been systematically covered in health professions' curriculum, thus specific references to guide the development of the resources were scarce.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

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Conflict of interest

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EDITED BY
Gustavo J. Nagy,
Universidad de la República, Uruguay

REVIEWED BY
Paulo Hilario Nascimento Saldiva,
University of São Paulo, Brazil

*CORRESPONDENCE
Lynn V. Monrouxe
✉ lynn.monrouxe@sydney.edu.au

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Triple planetary crisis: why healthcare professionals should care

Fathima Rizka Ihsan[1], Jacqueline G. Bloomfield[2] and Lynn V. Monrouxe[1]*

[1]Faculty of Medicine and Health, Sydney School of Health Sciences, The University of Sydney, Camperdown, NSW, Australia, [2]Faculty of Medicine and Health, Sydney Nursing School, The University of Sydney, Camperdown, NSW, Australia

Humanity currently faces an ecological crisis with devastating consequences to all living species. While climate change is estimated to lead to 250,000 extra deaths per year between 2030 and 2050, pollution is known to cause 9 million premature deaths: a figure much greater than the deaths caused by AIDS, tuberculosis and malaria combined. The healthcare sector is both burdened by, and contributes to, the impact of climate change and environmental degradation. Amidst glaring evidence of the interdependence of human health and the eco system, there is an urgent call for healthcare professionals to concern themselves with the triple planetary threat humanity currently faces. Without immediate mitigative measures, the future seems uncertain. Some healthcare systems at local, national and global levels have taken numerous initiatives to address, mitigate and adapt to these changes, however, these are not sufficient. A lack of awareness among healthcare professionals of the ecological crisis, its interconnectedness, and the role of healthcare in it, plays a significant role in the lack responsibility of healthcare professionals in this space. Therefore, this paper presents a discussion of the current landscape of the triple threat of climate change, loss of biodiversity, and pollution, while emphasising the contribution of healthcare professionals to it. Furthermore, interrelated concepts such as planetary health and eco-anxiety are briefly discussed. This perspective paper also presents several key prospective research areas that may lay the foundation for motivating healthcare professionals to play an active role in preventing and mitigating the ecological crises humanity currently faces.

KEYWORDS

planetary health, climate change, pollution, biodiversity, healthcare, eco-anxiety, ecological crisis

Introduction

The "triple planetary crisis" refers to three interconnected and critical environmental issues facing our planet: climate change, biodiversity loss, and pollution (1). Climate change is having monumental effects on a global scale. Its detrimental impact on human health and ecosystems is escalating, so much so that climate change has been recognized as the leading threat to human health in the 21st century (2, 3). The impact of pollution on human health has exceeded that of several diseases combined (4) and the present rate of decline in biodiversity is poorly known (5). The environmental and human health effects of the ecological crises have only begun to unravel, and the forecast seems devastating. The emotional implications are taking a

toll on the mental well-being of the population (6, 7). While the global healthcare sector has a central role of improving population health, at the same time it emits greenhouse gases equivalent to 514 coal-fired power plants (8): leading to a situation whereby the healthcare sector both contributes to, and is burdened by, the ongoing environmental degradation. Thus reinforcing a vicious cycle. Despite this immense negative role, the healthcare sector lags in its action to mitigate its impact on the environment. While some healthcare professionals are of the view that this is beyond their responsibilities (9), a lack of awareness of the triple planetary crisis and the role of healthcare in it is quite apparent among healthcare professionals (10–13). This paper aims to bring together these different yet interconnected constructs and make a case for the healthcare workforce to take on an active role in this daunting fight against the triple planetary crisis.

Ecological crisis

Climate change

Climate change is having an escalating detrimental impact on human health and ecosystems (14). Climate change has been referred to as persistent (over decades) "*changes in the mean and/or the variability of its properties*" (15). However, issues around causality of climate change have been variously attributed. On the one hand it has been argued that climate change "*may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use*" (15). Here, causality is deemed neutral or even in equal measures between natural and human factors. On the other hand, the construct of climate change has been exclusively used to refer to direct or indirect "*human activity that alters the composition of the global atmosphere* ***and which is in addition to*** *natural climate variability observed over comparable time periods*" (our emphasis) [(16), p. 3]. From this perspective, climate change is referred to as changes caused by human-led activities only. Indeed, it has been argued that human-led activities have led to climate change much more excessively than natural processes (17).

The key change that sets off the chain of catastrophic events of climate change is the rise in global surface temperature. Human-induced global warming is presently increasing at a rate of 0.2°C per decade (18). With an average temperature of 1.5°C above pre-industrial era, 2023 recorded the warmest year since direct observations began (19). A rise in the temperature from 1.5°C to 2°C is forecast to have serious negative impacts on all life on earth. This ranges from an increase in water scarcity by 14%, a twofold rise in the population exposed to extreme heat, a tenfold increase in arctic melting, the near disappearance of coral reefs, a 50% drop in crop output, diminished seafood yield, and a 50% decrease in our loss of biodiversity including vertebrates, plants and insects (20). The release of greenhouse gases (GHGs) is the main way in which humans contribute to climate change as GHGs capture heat resulting in a rise in global temperature that leads to a cascade of events. Furthermore, the time lag between a pulse of GHGs and its warming effects is about a decade (21). This suggests that the global community is yet to experience the true effects of our current actions.

Climate change and the healthcare sector

GHG emission sources are mostly electricity and heat, transportation, and agricultural processes that release carbon dioxide, methane and nitrous oxide and deforestation that lead to a loss of major carbon sinks (22). It is said that if the global health sector were a country, it would be the fifth largest carbon footprint generator in the world (23). In 2016, it was estimated that 4.6% of all greenhouse gas emissions worldwide originated from the healthcare sector while this figure was higher in Australia (7%) and the United States (9.8%) (24). Of the total greenhouse gas emissions from the healthcare sector, 71% were from its supply chain (24).

It is evident that climate change is causing environmental catastrophes on a global scale and significantly impacting all living beings. It is also affecting social and environmental determinants of health that lead to, among many others, an increase in the prevalence and severity of respiratory diseases including: asthma, vector-borne diseases, heat-wave-related deaths, food and water-borne diseases and mental health problems (25–27). Furthermore, adverse events directly impact access to healthcare and increases mortality (25). The World Health Organization (WHO) estimates that there will be an additional 250,000 deaths per year due to the implications of climate change between 2030 and 2050 (28). While it is recognized as a crisis multiplier due to its potential to aggravate existing threats, climate change has been declared the leading threat to human health in the 21st century by the WHO and The Lancet (2, 3). This positions the health sector in a complexity of being both burdened by, and contributing to, the impact of climate change and environmental degradation.

Pollution

Pollution in the forms of water, soil and air has greatly risen in recent times and is causing disastrous consequences for human health and the environment (4, 29). The Lancet Commission on Pollution and Health reported that all forms of pollution combined were responsible for an estimated 9 million premature deaths in 2015 which is three times greater than deaths caused by AIDS, Tuberculosis and Malaria combined (30). Water pollution caused by human activities and natural factors such as urbanization, inappropriate industrial waste disposal, climate change, poor water supply and sewage treatment and agriculture activities is responsible for an estimated 829,000 deaths per year (31, 32).

Pollution and the healthcare sector

Concerningly, air pollution is responsible for 6.4 million deaths (30) and air pollution is on track to increase by two-fold by 2050 (33). Diverse components of the healthcare system are contributing to pollution ranging from the cafeteria to the operating theatre. Major toxic air pollutants are released from healthcare facilities including

Abbreviations: IPCC, The Intergovernmental Panel on Climate Change; UNFCCC, United Nations Framework Convention on Climate Change; GHG, Greenhouse Gas; AIDS, Acquired Immunodeficiency Syndrome; WHO, World Health Organization; SGD, Sustainable Development Goals.

anesthetic gases, boilers, cooling, ventilation and incineration of medical waste and from the supply chain of healthcare comprising services and goods such as the pharmaceutical organizations (34–36). While soil pollution by heavy metals, toxic organic waste and nano and micro-plastics, impacts the agri-food system, it also affects soils' ability to store water and remove water contaminants (37). It has been recorded that an estimate of 87,000 tonnes of PPE and 144,000 tonnes of additional waste such as syringes and needles were generated during the first 1.5 years of the Covid-19 pandemic (38). Pollution of this vital constituent of the planet's infrastructure disrupts many ecosystem services and all forms of life on earth (37).

Untreated medical waste disposed of in landfills leads to contamination of water if improperly designed. Furthermore, consequences of the comparatively silent threat; chemical pollution, have not yet been adequately quantified, however, its effects of neurotoxicity, reproductive toxicity and immunotoxicity are of great concern (23). Inappropriate handling, storing or disposing of chemical disinfectants of healthcare wastes contributes to this alarming threat. Amidst these distressing statistics there exists a significant disparity between pollutions' impact on human health and the international resources directed towards its control; less than 2 billion dollars have been dedicated to pollution mitigation which is responsible for an estimate of 9 million deaths whereas more than 25 billion dollars have been designated to tackle AIDS, Malaria and Tuberculosis which lead to an estimate of less than 3 million deaths in total (4). This demonstrates the degree to which the international community views pollution as a serious threat.

Biodiversity

The Convention on Biological Diversity in 1992 defined biodiversity as "*the* var*iability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (39). In simpler terms it refers to the variety of life in genes, species, and habitats (40). Biodiversity is known to play a critical role in water purification, maintenance of soil quality and pollination directly affecting food and water essential for human life (41). The protective function of biodiversity has only recently begun to be appreciated. At present the world faces a global decline in biodiversity at a rate that is difficult to quantify and is inadequately recorded (42). While this is also caused by natural factors, the rate at which it occurs due to human activities far exceeds this natural process (42, 43). The main drivers of this include over-exploitation, climate change, invasive species and change in land use mostly due to agricultural expansion to meet the demands of global supply chains (44, 45).

Biodiversity and the healthcare sector

Biodiversity plays an essential role in drug discovery, biotechnology breakthrough and maintenance of ecosystems: a disruption of which would lead to the spread of diseases (41, 46). In addition to the complex healthcare supply chain, massive energy consumption by healthcare facilities for ventilation, heating and air conditioning purposes, the use of fresh water and waste generation resulting in loss of biodiversity and a significant strain on natural resources (47). Furthermore, evidence suggests that the human immune system is intricately linked to biodiversity exposure with reduced biodiversity being associated to increased prevalence of allergies and chronic inflammatory diseases in the urban population (48). The interdependence of human health and the eco system, amidst such evidence, is undeniable.

Planetary health and the education of health professions

Environmental activists, scientists, and educators are urging both the public and professionals to take immediate mitigative measures to combat what is now a current problem that threatens the future of civilization (49–51). Many position papers have called for the recognition of the ethical obligation of healthcare professionals to concern themselves with the triple planetary threat humanity faces (52–54) and the inclusion of planetary health in the health professions curricula (55, 56). Planetary health, defined as "*the achievement of the highest attainable standard of health, well-being, and equity worldwide through judicious attention to the human systems-political, economic, and social-that shape the future of humanity and the earth's natural systems that define the safe environmental limits within which humanity can flourish*" [(57), p. 1978], unifies and acknowledges interdependent relationships between living organisms and their ecosystems.

Successful mitigation of the challenges humanity faces requires trans and interdisciplinary and innovative strategies. Founded on five domains, of which "*the interconnection within nature*" plays a central role [(58), p. 253], planetary health focuses on human health and the natural systems within which humans exist (57). While it primarily focuses on human health, a shift from concepts such as one health and eco health (59), it is centered on the dependency of human health and well-being on planets health. Furthermore, it can be viewed as an "umbrella" field which encompasses existing concepts such as Public, Global and Environmental Health (60). Maintaining planetary health requires an understanding of interrelated natural systems of the earth and the health benefits that arise from conserving and restoring these systems. Therefore, a comprehensive and holistic approach to health, such as planetary health is better suited to address the unprecedented challenges humanity faces at present (48) and this can be in cooperated into health professions curricular by highlighting the need for healthy eco-systems for human health (60). Furthermore, the 17 United Nations Sustainable Development Goals (SGD) address crucial aspects of the environment ranging from climate action to inequalities. As the principles of planetary health and sustainable development goals (SGDs) are well aligned, planetary health may also be viewed as the visualisation of SGDs (61, 62).

However, the current healthcare landscape is rather different. While there are numerous sustainable healthcare initiatives at local, national and global levels, these are trivial considering the extent of the problem (63). Concepts of climate change have been minimally included in health professions curricular globally (64) and, likewise, the principles of planetary health in clinical practice have been applied narrowly (48). Evidence suggests that clinicians and nurses are of the perception that climate action is "*peripheral to their role of a healthcare professional*" [(9), p. 5] and that there are certain professionals whose roles such as public health

professionals are better suited than theirs to carry out this work (9). Additionally, some healthcare professionals feel there is minimal support from colleagues and superiors to communicate about climate change to the public and implement mitigative measures (65, 66).

Over the decades, healthcare professionals have played an active role in advocating and leading by example for health concerns such as sanitation and hygiene, tobacco control and the prevention of war (67). Why do healthcare professionals feel different in this instance, especially when the healthcare sector itself plays a key negative role? We argue that the problem is most likely due to a lack of understanding around this complex issue, alongside ignorance of what action is possible for healthcare professionals to take. Subsequently, we believe it is imperative to identify factors that affect healthcare professionals' sustainability practices. As an individual's perception, attitude and practices are influenced by contextual and cultural factors (68, 69), for transferability and practical implications, examination of influencing factors across diverse contexts will be valuable.

Eco-anxiety

With the rapidly growing concern about the ecological crisis, emotions related to it have gained substantial global attention (70). Studies exploring emotions related to the ecological crisis have been conducted by scholars from diverse disciplines in a range of cohorts such as specific communities, climate activists, adolescents, children, climate researchers, environmental educators and students (70–72). Eco-anxiety, a term coined to describe "*anxiety in relation to the ecological crisis*" [(70), p. 2], and climate anxiety, defined as "*forms of anxiety that are considerably related to the climate crisis*" [(70), p. 2], are commonly used interchangeably as labels for examining strong negative emotions related to our ecological crisis in literature (70).

While not implying mental illness, the vulnerability of children and adolescents to this has been reported (71–74). Indeed, a study conducted among adolescent psychiatrists in the UK found that 57% of their participants (comprising Child and Adolescent Psychiatrists in England) had seen a patient who was distressed about ecological issues during the past year (7), while another Australian-based study found that four out of five students felt "*somewhat or very anxious about climate change*" [(6), p. 1]. Furthermore, an American poll of among 4,400 females aged between 18 and 44 years found that 14.3% cited climate change as a major reason (and 20.7% cited it as a minor reason) for not having children (75). Against this background we might legitimately ask whether healthcare professionals are adequately informed and prepared to meet this demand for patient support.

Similarly, it is crucial for healthcare professionals to deal with their own emotions related to the ecological crisis prior to providing therapeutic interventions to their patients. Amidst the clear need for professionals trained in managing patients with eco-anxiety, the literature suggests that there is minimal guidance and scholarly work addressing this aspect (6). There is scarce evidence on the prevalence of eco-anxiety amongst the population of healthcare professions. While a recent study among Italian doctors is a great start (76), work in this space is still in infancy. Accurate assessment of eco-anxiety requires the use of validated tools designed based on the domains of eco-anxiety, therefore we encourage people to engage with the wider literature outside healthcare professions education to develop their thinking in this area.

Conclusion

With the rising disease burden, shifting population needs and ever evolving technology and treatment modalities, healthcare professionals are overwhelmed with the delivery of quality patient care (77, 78). Existing staff shortages and other resource constraints exasperate carrying out their responsibilities (77, 79, 80). In this context, healthcare professionals may view the ecological crisis beyond their scope of responsibilities and the gradual manifestations of its effects, adding to it. However, we believe that this perspective is detrimental to health in the long run. It is evident that the healthcare sector significantly contributes to the triple planetary crisis which has detrimental consequences on human health. This increases the need for healthcare, as well as the burden on the healthcare sector, which in turn further increases its environmental impact leading to a vicious cycle. With improving population health as its goal, we argue that it is only ethical that the healthcare workforce plays a pivotal role in the fight against these threats to human health.

Building a climate-conscious, resilient, and environmentally sustainable health workforce is imperative. The lack of awareness among the healthcare community regarding the interrelated aspects discussed in this paper and the negative contribution of the healthcare sector to it, seems to play a significant role in the lack of responsibility of healthcare professionals in this space (11–13, 81). Therefore, to shape the attitude of the current and future healthcare workforce to support and implement sustainable healthcare practices, the importance of education cannot be sufficiently emphasized. Globally, only a few educational institutions have incorporated the principles of planetary health into health professions curricula (82). Little is known about the perspectives of health professions' educators', who play pivotal and decisive roles in shaping the course of health professions education (83). Thus, understanding their viewpoints toward the principles of planetary health, sustainability, and the integration of these concepts into health professions curricular would lay the foundation in the healthcare sectors' role in preventing and mitigating our ecological crises. Without this crucial educational shift, the healthcare sector will remain ill-prepared to combat and mitigate the pressing ecological crises of our time.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

FI: Conceptualization, Writing – original draft, Writing – review & editing. JGB: Conceptualization, Supervision, Writing – review & editing. LM: Conceptualization, Supervision, Writing – review & editing.

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EDITED BY
Lynn Valerie Monrouxe,
The University of Sydney, Australia

REVIEWED BY
Gustavo J. Nagy,
Universidad de la República, Uruguay
Chiara Cadeddu,
Erasmus University Rotterdam, Netherlands

*CORRESPONDENCE
Zerina Lokmic-Tomkins
✉ zerina.tomkins@monash.edu

†These authors have contributed equally to this work

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Integrating planetary health education into tertiary curricula: a practical toolbox for implementation

Zerina Lokmic-Tomkins[1,2]*, Liza Barbour[3], Jessica LeClair[4], Jeneile Luebke[4], Sarah L. McGuinness[2,5], Vijay S. Limaye[6,7], Parvathy Pillai[7], Maxfield Flynn[8], Michael A. Kamp[6], Karin Leder[2†] and Jonathan A. Patz[6,7†]

[1]School of Nursing and Midwifery and Health and Climate Initiative, Monash University, Clayton, VIC, Australia, [2]Division of Planetary Health, School of Public Health and Preventive Medicine and the Health and Climate Initiative, Monash University, Melbourne, VIC, Australia, [3]Department of Nutrition, Dietetics and Food, Monash University, Clayton, VIC, Australia, [4]School of Nursing, University of Wisconsin, Madison, WI, United States, [5]Department of Infectious Diseases, Alfred Hospital, Melbourne, VIC, Australia, [6]Center for Sustainability and the Global Environment, Nelson Institute for Environmental Studies, University of Wisconsin, Madison, WI, United States, [7]Department of Population Health Sciences, University of Wisconsin, Madison, WI, United States, [8]School of Medicine and Public Health, University of Wisconsin, Madison, WI, United States

Objective: To present a series of case studies from our respective countries and disciplines on approaches to implementing the Planetary Health Education Framework in university health professional education programs, and to propose a curriculum implementation and evaluation toolbox for educators to facilitate the adoption of similar initiatives in their programs. We emphasize the importance of applying an Indigenous lens to curriculum needs assessment, development, implementation, and evaluation.

Methods: Case studies from Australia and United States were collated using a six-stage design-based educational research framework (Focus, Formulation, Contextualization, Definition, Implementation, Evaluation) for teaching planetary health and methods of curriculum evaluation. These components were then mapped to derive the curriculum implementation toolbox reflecting the six-stage design-based educational research framework.

Results: The case studies demonstrated different approaches to successful integration of the Planetary Health Education Framework in medicine, nursing, public health, and allied health disciplines. This integration often involved Indigenous perspectives on environmental stewardship, holistic health, and community well-being into the curriculum. The case studies also highlighted the importance of community engagement, cultural competency, and interdisciplinary collaboration in curriculum development. Findings from case studies were used to propose a curriculum implementation toolbox to assist educators in adapting and integrating planetary health education into their own programs.

Discussion: While valuable frameworks for teaching planetary health in health science programs exist, challenges remain in implementing these frameworks in real-world educational environments. The proposed curriculum implementation toolbox offers practical strategies and resources for educators to incorporate these principles into their teaching. Additionally, the case studies reported here

contribute to the growing body of literature on planetary health education pertinent to addressing the triple planetary crisis.

KEYWORDS

planetary health, climate change, environment, education, curriculum development, implementation

1 Introduction

Indigenous Peoples have a deep connection to the natural world, often viewing themselves as an integral part of the environment rather than separate entities. This connection encompasses spiritual, cultural, and practical dimensions, guiding their stewardship practices and sustainable lifestyles through sophisticated knowledge systems emphasizing respect, reciprocity and harmony with nature. In contrast, it is only over the past 60 years that Western science and medicine have directly recognized the close link between our health and the environment. Rachel Carson's 1962 book, *Silent Spring*, highlighted the impacts of environmental chemicals on songbirds, serving as a wake-up call. In 1987, the United Nations World Commission on Environment and Development published *Our Common Future*—also known as the Brundtland Commission Report—introducing the concept of Sustainable Development (1). The following year, the World Meteorological Organization and United Nations established the Intergovernmental Panel on Climate Change (IPCC) to scientifically assess climate change impacts (2). These events underscore three core challenges we face today—the triple planetary crisis of climate change, pollution and biodiversity loss—each threatening the health of current and future generations (3).

While Earth's climate naturally changes over time, human activities, particularly the unchecked extraction and burning of fossil fuels, have significantly increased the amount of greenhouse gasses in the atmosphere, driving Earth's warming. Climate change and pollution are interlinked and their consequences include global temperature shifts; land surface changes; melting ice sheets and sea-level rise; increased intensity and frequency of bushfires/wildfires, heatwaves, storms, floods, and droughts; as well as famine, social disruptions, ecosystem loss and species extinctions (4, 5). There are myriad of long term effects health effects and significant socioeconomic costs (5), often disproportionately affecting Black, Indigenous, low-income, and multispecies communities at the frontlines of climate disasters and industrial pollution (6, 7). Pregnant women, infants and children are also highly susceptible, with resulting reproductive health impairments and adverse pregnancy outcomes (8). Additionally, air pollution can harm cognitive function and increase dementia risk (9).

Biodiversity loss, driven by human activities including deforestation and agriculture, as well as natural disasters such as bushfires, reduces the variety of plant and animal species. This loss leads to crop failures and food insecurity (10), depletes potential sources of medicinal compounds from plants and microorganisms (11), and adversely impacts human physical and mental health (12). Additionally, habitat destruction increases human-animal contact, heightening the risk of zoonotic diseases. This underscores the importance of natural habitat protection (13) and ecological restoration as measures for disease prevention (14).

To promote planetary health, efforts must address the impacts of climate change, pollution and biodiversity loss at community, policy, and systems levels (15). As a carbon emitter and polluter, the healthcare sector must also adopt environmentally sustainable practices, including transitioning to renewable energy sources, revising anesthetic and inhaler protocols and minimizing single-use products and plastics (16). Additionally, the sector must pioneer innovative care models, adopt environmentally sustainable digital health solutions (17), promote reductions in transport-related emissions (16) and provide clinical governance improvements to assure sustainable care delivery. Consumer engagement and prevention investments are key for reducing healthcare demand and facilitating healthcare sector-driven systemic change to promote sustainable and equitable access to healthcare (18).

Building healthcare and public health workforce competencies begins with pre-registration education and is strengthened through lifelong learning and mentoring (19). Since the publication of the Planetary Health Education Framework (Figure 1) to address the planetary triple crisis (20), healthcare and public health educators have been working to integrate this framework into their overcrowded curricula. To meet the urgent calls from experts on bold action, widespread integration of planetary health education across health disciplines is essential. However, curriculum developers face barriers in mainstreaming planetary health education.

This paper presents a series of case studies from medicine, nursing, public health, and allied health disciplines where the framework has been implemented and offers a toolbox for educators to facilitate similar initiatives in their programs. Rather than attempting to be a comprehensive review of all available curricula, we focus on learnings from our experiences at the University of Wisconsin, Madison in the United States, and Monash University in Melbourne, Australia. By sharing our specific experiences, we aim to provide practical examples of progress, barriers, opportunities and innovations in advancing Planetary Health curricula and education.

1.1 Positionality statement

This article was written by scholars who identify as non-Indigenous to Australia (Z.L-T, L.B, S.L.M, K.L), non-Indigenous to the United States (USA; JLeC, V.S.L, P.P, M.F, M.A.K, and J.A.P) and one Indigenous scholar (J.L.), who identifies as an enrolled member of the Bad River Band of Lake Superior Chippewa in Wisconsin, United States.

Jeneile states: "As an Indigenous author, my community and I welcome the collaboration and allyship of non-Indigenous authors, as well as their dedication and commitment to uplifting the voices of the Indigenous community."

As non-Indigenous authors, we have approached this manuscript with a commitment to allyship, aiming to support and amplify Indigenous voices and knowledge systems. We have undertaken this work from the perspective of non-Indigenous educators and

researchers, with a deep dedication to fostering inclusive, culturally responsive, and transformative learning environments. Our collective professional backgrounds in nursing, medicine, public health, and education have shaped our understanding of the complex global challenges addressed by planetary health, particularly at the intersection of environmental sustainability and human well-being.

We further acknowledge that while we each bring different life experiences, positionalities, and biases, we have made every effort to honor Indigenous contributions. This paper reflects our ongoing learning, reciprocity, and commitment to integrating Indigenous knowledge in the effort to address global planetary health challenges.

2 Case studies of curriculum development and implementation

2.1 Early adopters of planetary health

In 2015, the Rockefeller Foundation–*Lancet* Commission on planetary health released a report that concluded human civilization is mortgaging our future health for current economic growth and development (21). The health of future human civilization depends on thriving natural systems that help provide humans with clean air, clean water, and a buffer against disease outbreaks (21).

Since the report, the planetary health field has grown across the globe and universities are increasingly emphasizing the necessity of using a planetary health lens in education, regardless of the occupation students choose. For example, the London School of Hygiene & Tropical Medicine offers a MSc in Climate Change and Planetary Health (22), and the University of Edinburgh offers a MSc in Planetary Health (23). However, these are only two examples of planetary health education in an area that is growing worldwide.

To serve as a central hub, the Planetary Health Alliance, now led out of Johns Hopkins University in the United States, creates and circulates educational materials and plans annual meetings every 18 months to bring the field together (15). A key educational piece distributed has been the framework on Planetary Health Education (Figure 1) (20).

2.2 Medical education

In 2015, leadership from 118 health professions schools worldwide, including the University of Wisconsin School of Medicine and Public Health (UWSMPH), signed the Global Health Educators Climate Commitment, pledging to train the next generation of health professionals to effectively address the health impacts of climate change (24). Since then, there have been multiple calls to action by

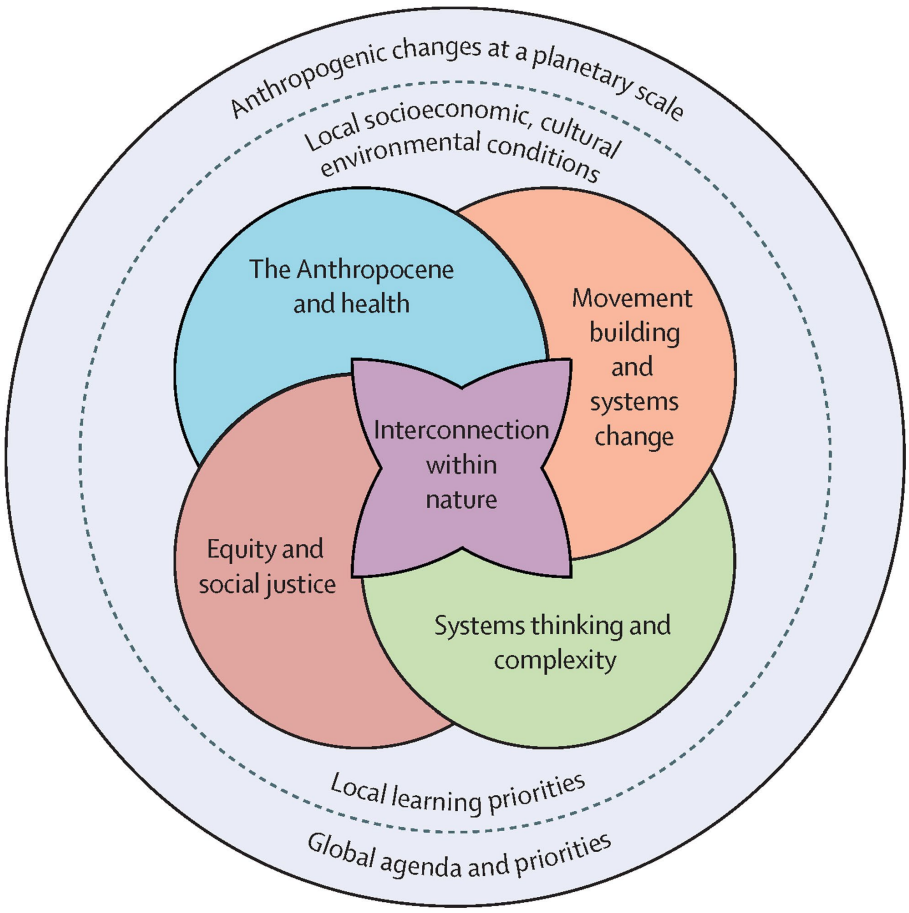

FIGURE 1
Reproduced from Faerron Guzmán et al. (20) by permission of the authors.

medical students, faculty, and medical organizations for curriculum on the impacts of climate-related health effects, planetary health and sustainable healthcare (25–29). There are growing examples of how these curricula can and have been incorporated across the continuum of education for medical students to practicing providers (30, 31) and the development of a repository for such curriculum (32). Assessment of planetary health topics have been developed for licensing board examinations for practicing physicians within the United States (personal communication, Cecilia Sorensen 2024), and requirements of the Liaison Committee on Medical Education (the accrediting authority for US medical schools) to address common societal problems, further justify incorporating content on the triple planetary crisis (33, 34).

The UWSMPH MD curriculum now has planetary health-related content in five of the six required preclinical courses that span across the first 18-months of the medical school curriculum. Learning modalities include lectures, small group self-directed learning on asthma and an asynchronous video focused on climate change-related moral injury. There is also a panel discussion featuring Wisconsin tribal community members speaking on food sovereignty, health equity, and the importance of biodiversity and land stewardship. Additionally, students can take a two-week "Climate Change Medicine" elective.

Barriers identified for adding planetary health curriculum include lack of perceived time within the existing curriculum and limited climate change expertise among faculty within UWSMPH. Using existing frameworks (35, 36), a plan has been developed to introduce additional brief asynchronous online videos, rather than time-intensive lectures, and to use these as prework for clinical case-based small-group discussions across preclinical and clinical courses. These efforts will thereby incorporate planetary health considerations into existing pathophysiology-oriented case scenarios.

2.3 Public health education

Black, Indigenous, and other racialized groups in the United States are experiencing worse health impacts from the planetary crisis than white communities (37). To support effective addressing of these health inequities, the American Public Health Association and the U.S. Centers for Disease Control and Prevention's Climate and Health Program provide technical assistance for local jurisdiction climate planning, identifying and engaging partners, and prioritizing community-driven interventions.

The Global Network for Academic Public Health emphasizes the role of public health schools and programs in planetary health. In the United States, the National *Core Competencies for Public Health Professionals* direct frontline public health staff to assess community health vulnerability and risks associated with climate change; to communicate environmental impact factors; to collaborate with communities to reduce health inequities by promoting environmental justice; to assess, develop, and implement organizational policies, programs, and services to advance environmental justice. The Association of Schools and Programs of Public Health (ASPPH) has established core competencies for Masters of Public Health (MPH) trainees across five domains (biostatistics, environmental health, epidemiology, health policy and management, and social and behavioral sciences) and seven cross-cutting domains (communications and informatics, diversity and culture, leadership, professionalism, program planning, public health biology, and systems thinking) (38). These core competencies operate as guidelines for accredited schools of public health and a benchmark for non-accredited programs.

Historically, the environmental health domain of MPH training has focused on air and water contamination, drawing on study of well-studied pollutants such as lead, asbestos, and airborne particulate matter. Efforts are underway to enhance core competencies with climate change content through the Climate Change and Health for Public Health Education Toolkit, published in 2022 by the Association of Schools & Programs of Public Health (ASPPH), a US-based organization representing public health schools and programs accredited by the Council on Education for Public Health in the United States and globally (39). Developed with the Global Consortium for Climate and Health Education (GCCHE) (40) this program offers guidance for integrating climate and health content within existing core competency frameworks (35), spanning knowledge and analytical skills, collaboration and communication, policy, public health practice, and clinical practice domains (35). It is of note that GCCHE has developed a suite of free, globally available online courses designed to educate interdisciplinary professionals on the health impacts of climate change and empower them to take action within their fields and communities (41).

At UW-Madison, MPH students typically satisfy their environmental health coursework requirement with a common overview course and engage with planetary health content through elective courses, including health-focused classes on air pollution, climate change, and planetary health (42). The elective courses draw on interdisciplinary approaches and lectures from experts in nursing, environmental studies, chemistry, and zoology from other campus departments. Public health students pursuing MS and PhD degrees also take these electives and integrate planetary health training into their research training through joint, double, and dual degree programs (43) which facilitate interdisciplinary training and research experiences but can require additional course-loads. They enhance student fluency and covering areas such as biodiversity threats to disease spillover risks (44), extreme heat (45), and indoor air pollution (46).

2.4 Nursing education

Recognizing the growing climate crisis, the International Council of Nurses (ICN) has integrated climate change into its Code of Ethics (47), and, along with the American Nurses Association (ANA) Code of Ethics, inspires nurse action and advocacy for environmental preservation (48). The ANA recently issued a statement on nursing's responsibility in addressing climate change and climate justice, urging integration of climate and health science into nursing education (49), and also updated the scope and standards of public health nursing to include environmental and planetary health and environmental justice (50). The National Academies of Sciences, Engineering, and Medicine's Future of Nursing 2020–2023 report highlights the intersection of environmental health, racism, discrimination, planetary disasters, and implications for nursing (51).

Growing support exists for integrating planetary health into nursing curricula. For example, the Nurses Climate Challenge, a collaboration between the Alliance of Nurses for Healthy Environments and Health Care Without Harm, aims to educate nurses about climate change, partnering with nursing schools to embed climate change content into curricula from baccalaureate to doctoral programs (52). It shares educational and advocacy materials on climate change impacts for nurses to use in educating colleagues and patients. Nurse scholars have proposed adding planetary health as the ninth concept in the American Association of Colleges of Nursing (AACN) Essentials competency-based education framework (53). While the AACN has not adopted this yet (54), following Flatten et al. (53), the UW-Madison School of Nursing plans to integrate planetary health as a concept that, like diversity, equity, and inclusion, will be woven across AACN Essentials domains and competencies. The Planetary Health Education Framework is successfully applied to support the implementation of the AACN Essentials in nursing education (53). The Nursing Planetary Health Report Card is another international transdisciplinary student-led initiative to assess schools' work in planetary health and suggest improvements (55).

The University of Wisconsin (UW)-Madison School of Nursing offers undergraduate, Doctor of Nursing Practice (DNP), and PhD programs, integrating planetary health topics across all programs since 2018. Faculty utilize exemplars to demonstrate how nursing concepts can be applied to multiple issues. The Social Ecological Model is taught across subjects to demonstrate nursing strategies for addressing planetary health at various levels. Students engage in readings and a lecture on communication strategies related to planetary health and climate justice, and collaborate to devise pitches for implementing the Nurses' Climate Challenge initiative in clinical sites or future workplaces. Classroom sessions often feature guest speakers, including sustainability experts from local health systems, enhancing student learning.

The Australian Nursing and Midwifery Accreditation Council (ANMAC) is the accreditation authority responsible for accrediting education providers and programs of study for the nursing and midwifery profession in Australia (56). Currently under review, the Registered Nurse Accreditation Standards (2019) outlines in *Standard 3: Program of Study* that *'Teaching and learning reflects contemporary practices in nursing, health and education, and responds to emerging trends based on research, technology and other forms of evidence.'*(Standard 3.4) and that the program's content and subject learning outcomes ensure '*integrated knowledge of regional, national and global health priorities, including mental health and care of the older person*' (Standard 3.5 b) (57). Thus, to meet Standard 3.5b, nursing preregistration programs must demonstrate the integration of contemporary issues impacting the nursing profession, such as the United Nations Sustainable Development Goals (58). In response, the Planetary Health in Nursing & Midwifery – Research & Education Collaborative produced a planetary health curriculum framework, inclusive of Indigenous knowledges, outlining key knowledge and skills with a specific focus on climate change (59). Disseminated via the Council of Deans of Nursing and Midwifery, this framework helps Australian nursing schools meet ANMAC's Standards 3.4 and 3.5b on planetary health. The next challenge is to embed the planetary health framework into the upcoming accreditation standards, an essential step toward equipping the entire future Australian nursing workforce to engage and lead in planetary health.

2.5 Centering Indigenous voices in the promotion of planetary health in nursing

Indigenous-specific knowledge and planetary health have been integrated into the nursing curriculum at the UW-Madison School of Nursing through our annual Native Nations Nursing, Helpers, and Healers (NNNHHS) summit, held each fall. The summit has been designed and refined over the past 10 years to strengthen community-academic partnerships between the University and the 12 sovereign tribal nations in Wisconsin. The NNNHHS summit emphasizes the collaborative efforts necessary between Indigenous communities, tribal leaders, healthcare providers from both tribal and non-tribal entities, community members, and researchers to deliver effective health programs tailored to promote the health and wellbeing of Indigenous peoples and their communities. The summit also brings future healers, faculty, staff, and community members as a learning and healing community. Due to the continuation of colonial influences and systems, there are limitations in exposure and opportunities to learn about Indigenous ways of knowing and being. Therefore, the NNNHHS summits provide a safe place for students, faculty, healers, and community members to come together and learn from one another. Blending Western sciences with traditional Indigenous knowledge and values to best meet Indigenous patients' needs is important, as is centering planetary health and justice in our work.

There has also been a purposeful integration of planetary health within the undergraduate and graduate nursing curriculum, with incorporation of several modules emphasizing the intersection of environment and health and the impact of climate change on the health and wellbeing of individuals, families, and communities. There is also an emphasis on historically excluded populations, including Indigenous communities in North America and globally, which serves as a step toward decolonization of the curriculum.

Indigenous peoples hold deep generational knowledge of their environments and sustainable practices that can significantly contribute to addressing climate change and promoting planetary health (60, 61). They also have vast experience managing delicate ecosystems through sustainable practices that have been honed and passed on for centuries. Indigenous perspectives can offer invaluable lessons critical to addressing climate justice and promoting planetary health (60, 61), and providing insights as the protectors and stewards of their lands (60).

Many Indigenous Peoples and communities have associated human-caused climate change and land degradation with femicide against our Mother Earth, a powerful concept that underscores the severity of human-caused climate change as well as ongoing land degradation and destruction. It also highlights the interconnectedness and intersectionality of environmental destruction and violence against Indigenous women, drawing attention to how both result from systems of exploitation and disrespect for life in all forms. Equating climate injustice with femicide is an urgent call to action to recognize and rectify the harm we are causing the planet (60), and recognizes respect of the feminine and Indigenous health and land tenure rights as interconnected determinants of planetary health (60). Indigenous communities often have traditional laws and practices that inherently respect the natural world, and tribal nations have been the leaders in implementing Rights of Nature legislation within their sovereign territories (60). These perspectives are increasingly being recognized and integrated into modern legal frameworks by implementing "rights

of nature" laws, for which Indigenous peoples' traditional ecological knowledge can be a valuable foundation.

2.6 Allied health education

Dietitians can help transform two key systems contributing to climate change, pollution, and biodiversity loss: the food system and the healthcare system. The current food system contributes a third of global greenhouse gas emissions, while driving diet-related disease and biodiversity loss, with dominant agricultural practices threatening 86% of species at risk of extinction (62, 63).

In Australia, recently updated dietetic competency standards contain greater emphasis on planetary health (64, 65). The Code of Conduct also requires dietitians to "participate in efforts to support progress toward sustainable food production, food systems and food and nutrition security for all, where possible" (66). Monash University offers both undergraduate and postgraduate degrees (Bachelor of Nutrition Science and Masters of Nutrition and Dietetics). However, current accreditation standards lack adequate planetary health curricula to prepare the future nutrition and dietetics workforce to address the triple planetary crisis. Therefore, Monash University educators and program directors are proactively integrating planetary health education into their curricula.

The approach has differed for each program (Table 1). The undergraduate program includes a dedicated unit on food sustainability systems, while the postgraduate program integrates a 'food systems' lens throughout the curriculum. This integration allows students to engage with planetary health education throughout their classes, placements, research and assessments. Monash is not the first to apply a food systems lens to their dietetic programs (67, 68), and future research will examine the impact of this approach on learner experiences and graduate attributes.

In both programs a 'Public Health Nutrition' unit offers a workshop co-designed by educators and students. The workshop emphasizes values-based practice, focusing on reciprocity and respect that are critical to Indigenous peoples' practices to maintain sustainable food systems in Australia for over 65,000 years (69). This co-designed curricula, part of a Faculty-wide fellowship project, will be shared with educators from other disciplines to support the integration of more planetary health content in their programs.

2.7 Interdisciplinary education

While current accreditation standards do not require planetary health curricula, the Monash's Master of Public Health Program introduced a "Global and Planetary Health" stream in 2023. As part of a faculty initiative, educators were encouraged to become "planetary health education champions." In this context, students and educators created interconnected learning activities, an example of which was on melioidosis for the Infectious Diseases Epidemiology unit. Figure 3 outlines the co-design and implementation process, designed to facilitate student input on content and delivery to enhance the learning experience.

Melioidosis, caused by the bacterium *Burkholderia pseudomallei*, is an infectious disease affecting humans and animals, particularly in Southeast Asia and northern Australia. It highlights the connection between planetary health and infectious diseases, reflecting key aspects of the Planetary Health Education Framework (Table 2) (20). This includes illustrating how climate change and ecosystem disruptions affect disease risk and epidemiology, and showcasing equity issues in the uneven distribution of environmental and health

TABLE 1 Overview of planetary health curricula in nutrition and dietetics programs offered at Monash University.

Program	Bachelor of nutrition science	Masters of nutrition and dietetics
Approach to embedding planetary health curricula	A stand-alone, compulsory unit 'Food Sustainability Systems' was developed and first delivered in 2016. The unit is facilitated by two educators with expertise in planetary health.	A 2022 curriculum review led to embedding a 'food systems approach' to the whole dietetics program. Educators with varying levels of expertise in planetary health facilitate this curriculum across multiple units.
Description of planetary health curricula	Learners complete this 12-week unit, with a 3-h in-person workshop each week in addition to self-directed pre-class (~2 h) and post-class (~1 h) activities.	Learners complete a dedicated unit 'Food systems for nutrition and dietetic practice' and complete food systems-oriented activities during their clinical and public health placements.
	Prioritization is given to pre-, in-and post-class activities that expose learners to Indigenous peoples' knowledge about food systems.	
Learning and teaching examples	Assessment tasks: Learners conduct a comprehensive Food System Audit of their chosen local government area and present an oral Counselor Brief, with prioritized, evidence-based policy actions to improve planetary health outcomes. Field trips: (i) Local urban agriculture site supplying a state-wide food relief charity, and (ii) Foodbank for people seeking Asylum in Australia, exemplifying dignified and inclusive emergency food relief.	Workshop activities: Learners are introduced to the key drivers, prevailing power relations within food systems, and the role of dietitians in navigating these in various 'micro food systems' to promote planetary health and equity. Field trips: (i) Facilitated workshop on soil health, composting and urban agriculture at an urban farm and social enterprise hub, and (ii) Guided tour of an on-campus residential food service focused on reducing food waste, using seasonal and local produce and connecting with on-site fruit, vegetable and herb gardens.

impacts. Despite its global importance, melioidosis remains under-recognized, perpetuating existing inequities (70).

3 Curriculum implementation toolbox

Regardless of the discipline where the planetary health education curriculum framework has been implemented, there are common principles that can be derived from each of the above case studies. These common principles are summarized in Figure 2 and encompass curriculum needs assessment, design and development, implementation and evaluation.

3.1 Curriculum needs assessment

The call for curriculum change reflects society's demand for health professionals to deliver safe, quality healthcare. These demands are often reflected in accreditation requirements and associated competencies although sometimes these lag behind societal norms. To assess the need for such change and to bring the project into focus (71), a curriculum needs assessment can evaluate the current state and identify what to teach within the human health-environment connections. There are three components to consider: (1) What are the needs of target learners; (2) What is the goal of the curriculum; and (3) in which context will this curriculum be delivered? Required data can be gathered through surveys, interviews, focus groups, auditing the existing curriculum and engaging key partners (employers, students, experts, etc.,) to understand student needs, employer needs, accreditation standards and relevant competencies. These data are also essential for leadership buy-in as their support enables required resources to be made available for curriculum development, implementation and evaluation (72). Regardless of discipline, some common principles apply to embedding planetary health education in the curriculum, such as top-down approaches driven by accreditation and regulatory requirements, and bottom-up approaches led by students and educators. Engaging various stakeholders, including Indigenous Peoples, community members, healthcare providers, policymakers, educators, and students, is essential in curriculum needs assessment.

To assess learner needs, the first question to ask is: Who are our learners? What would learners want to know or achieve in the context

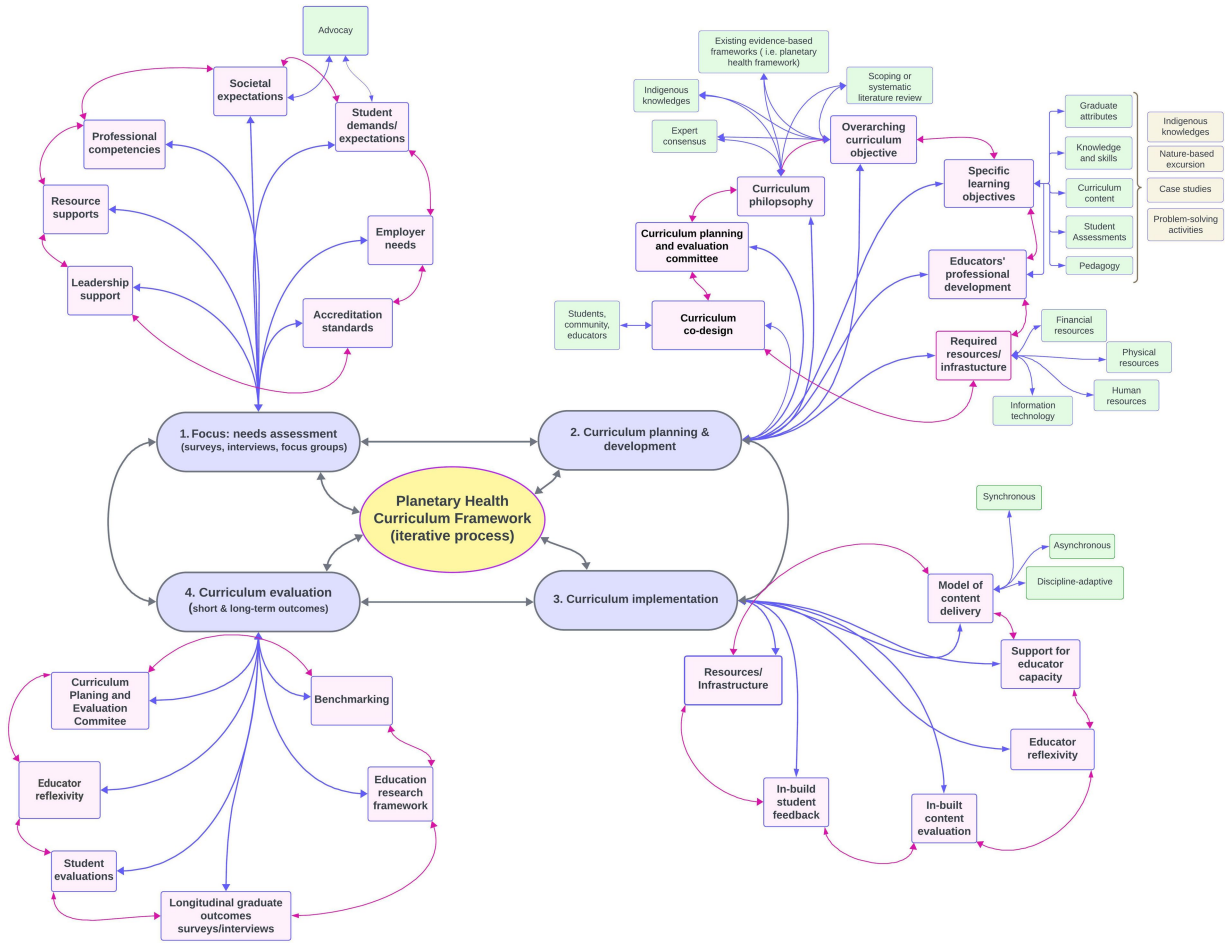

FIGURE 2
The curriculum development process consists of overlapping, iterative stages (mauve boxes). Each stage functions both as an individual process and as inputs and outputs (gray arrows) for the overall discipline-accommodating planetary health curriculum framework (yellow box). Each subcomponent of the curriculum framework (pink boxes) is interdependent (pink arrows), where the quality of each component affects the quality of the others. Additionally, each building block may require further consideration to meet the specific requirements of its aim (green boxes).

TABLE 2 Alignment of melioidosis case study with planetary health education framework and key planetary health concepts.

Planetary health education framework domain	Key concept	Alignment with example of melioidosis
Anthropocene and health	Climate change	• Increased rainfall and temperature linked to higher melioidosis risk (89) • Geographic expansion of melioidosis during La Niña events (90)
	Land-use change and ecosystem disruptions	• Urban expansion and construction associated with melioidosis cases (91)
	Globalization and other human activities	• Melioidosis spread to non-endemic areas through commercial products (92) and pet animals (93)
Systems thinking	Dynamic interactions among complex systems	• Complex interactions between risk factors (e.g., diabetes), socio-economic conditions, healthcare system capacity and disease risk and outcomes
Equity and social justice	Uneven distribution of disease impacts	• Disproportionate impact on rural poor populations in low-and middle-income countries (70) • Variation in mortality rates reflecting differences in healthcare access and risk factor prevalence (70)
Movement building and systems change	Advocacy	• Calls to recognize melioidosis as a neglected tropical disease for increased awareness and funding (70)

of planetary health education? This can be assessed by involving as many relevant key players as can be identified. Including healthcare providers, policymakers, educators, and students as key players also helps and can be achieved by developing a Curriculum Planning and Evaluation Committee. Assessing prior knowledge and current attitudes toward environmental issues and their personal connection to the natural world, can be leveraged to create a scaffolded curriculum. Such data can inform strategies for fostering environmental awareness and responsibility and establishes a baseline understanding of concepts like climate change and biodiversity, aiding in measuring curriculum impact. Considering student engagement in the digital age and potential impacts of generative artificial intelligence on assessment components are key strategies to ensure authentic learning (73).

3.2 Curriculum planning and development

To contextualize the pedagogy, the process of developing clear and measurable *learning objectives, activities, assessments and resources* for the planetary health curriculum starts with reviewing and adapting the Planetary Health Education Framework for health science education (20) to reflect local needs. The learning outcomes must encompass knowledge, skills, and dispositions necessary to understand and address planetary health challenges, in particular the triple crises of climate change, pollution and biodiversity loss. National professional accreditation standards exist to ensure the curriculum aligns with their expectations, and these can be further extended through UNESCO's Education for Sustainable Development competencies (74). The curriculum philosophy, which will provide a set of common values and principles to guide all subsequent decision-making when developing, evaluating and refining the curriculum, can be developed in collaboration with the Curriculum Planning and Evaluation Committee (75).

To develop necessary knowledge, skills and graduate attributes, the pedagogical strategies and the curriculum must be tailored to geographical context and locally relevant climate challenges, prioritizing key topics and concepts resonating with the student's sense of belonging to the place. Structural reforms may be necessary in how diverse knowledges are produced and disseminated (76). To ensure a comprehensive exploration of human-environment interconnectedness, use realistic case studies to integrate climate change, water quality, biodiversity loss, food systems, and sustainability for culturally appropriate and locally relevant action decisions (77). The Planetary Health Alliance provides a suite of case studies for this purpose (78). Balancing of content depth with breadth across various planetary health issues, while fostering hope and empowering students to act, is required.

The Planetary Health Alliance defines planetary health as a solutions-oriented, transdisciplinary field and social movement focused on analyzing and addressing the impacts of human disruptions to Earth's natural systems on human health and all life on Earth' (15). A transdisciplinary approach involves integrating knowledge and methods from various disciplines, including non-academic perspectives, to address complex real-world problems. This approach is crucial for implementing practical solutions in real-world settings because it brings together diverse stakeholders, including policymakers, practitioners, and community members, ensuring that solutions are holistic and applicable in practice (79). While a transdisciplinary approach is essential for implementing practical solutions in real-world settings, the core of planetary health education lies in interdisciplinary connections. This refers to the collaboration and integration of insights from different academic disciplines to understand and address the complex challenges of planetary health. In education, the emphasis is on fostering interdisciplinary connections because they enable students to develop a comprehensive understanding of planetary health issues, considering their biological, environmental, social, and economic dimensions (80). This broad-based understanding is crucial for identifying and analyzing

problems before they can be addressed through transdisciplinary action (81).

To reproduce this in the classroom, encourage diversity by bringing together students from different backgrounds such as social sciences, language arts, agronomy, environmental studies, engineering, or mathematics, alongside those in healthcare, public health, and veterinary medicine. Explore ways to infuse planetary health concepts into various subject areas for a holistic understanding. However, evidence suggests that health professions educators have limited capacity and confidence to teach planetary health (82), likely due to emerging nature of this field and their lack of formal training. Involving students as partners in curriculum development, using the principles of co-design, offers a practical approach to increase student engagement and educator capacity (83), as outlined in the case of melioidosis (Figure 3).

Perhaps the most challenging aspect of any curriculum design is creating authentic assessments, particularly those that bring a group of diverse individuals together. Developing formative and summative assessments to gauge student learning and the effectiveness of the curriculum while reflecting genuine engagement with the planet is difficult. Usually, formative assessments involve quizzes, discussions, or self-reflection activities; our suggestion is to replace these activities by involving nature into the teaching and assessment tapestry. Using longitudinal case studies reflecting real-world environments as highlighted above, students can be grounded in experiential, scaffolded learning about the interconnectedness of nature and human health. For summative assessments which traditionally include projects, presentations, or essays, consider expanding these to meaningful engagements with real community needs, such as Indigenous Peoples health needs and Indigenous knowledges. Students can be taught to critically evaluate data to develop innovative solutions to environmental challenges (77). While technology can enhance learning and engagement with planetary health topics, it can also alienate us from the natural world (84), so where technology is used, for example simulations, online databases, or interactive presentations, consider how can these support citizen science projects that focus on planetary health (85). Another consideration is managing and enhancing learners' tolerance of uncertainty. The climate crisis is filled with uncertainty, and educators must nurture favorable responses to uncertainty in the way they develop and implement planetary health education. This can be achieved through strategic use of stimulus and moderators, as explained by Lazarus and Stephens in their handbook for educators, which includes discipline-specific examples of planetary health education (86).

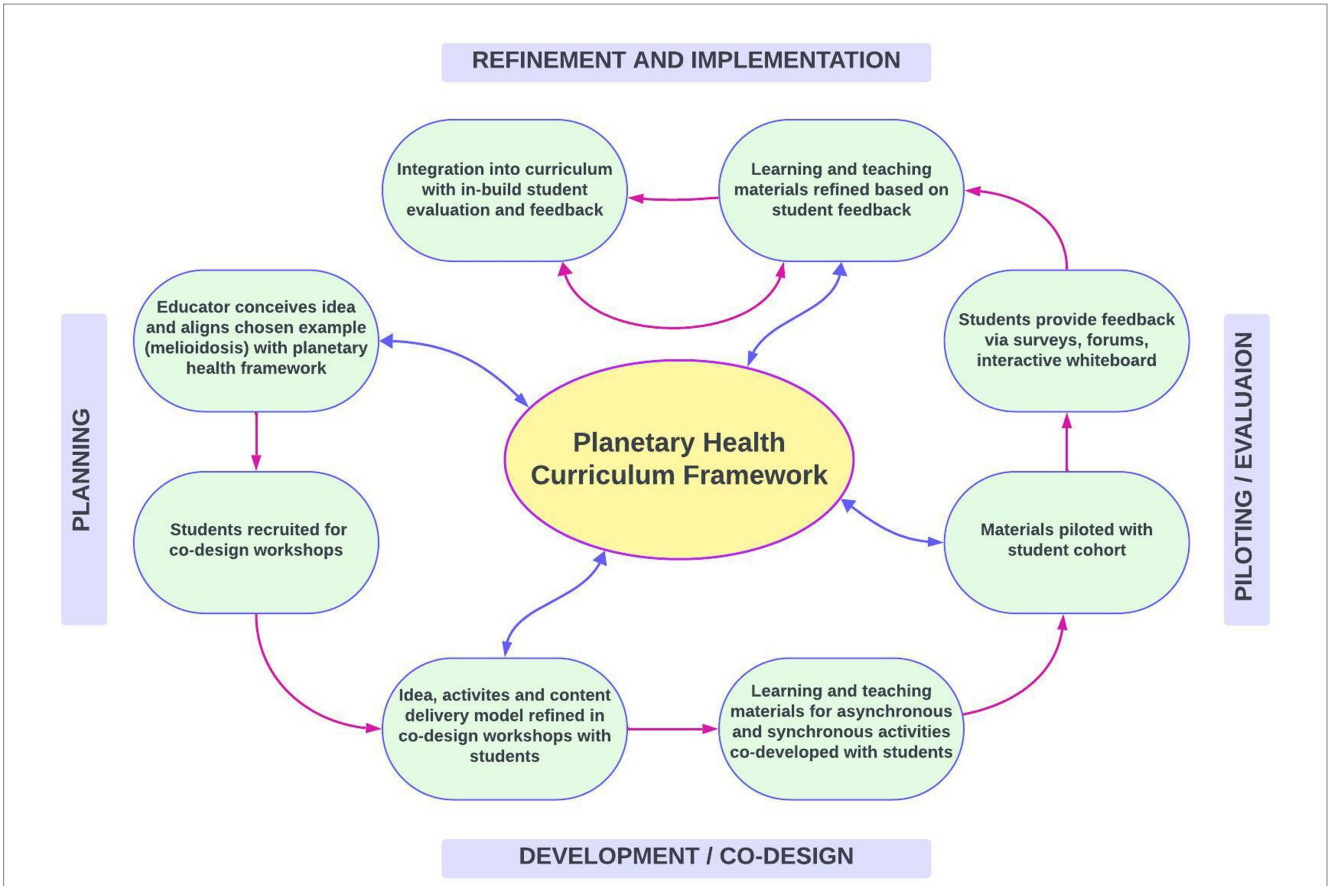

FIGURE 3
Co-Design and implementation process for a series of learning and teaching activities focused on melioidosis, including asynchronous activities (student-led introductory video on planetary health, drag-and-drop activity illustrating how individual, public and one health concepts relate to planetary health, short lecture on the intersections between melioidosis and planetary health) and a synchronous in-class workshop (based on a hypothetical melioidosis case drafted by students). Materials were piloted with students and refined based on feedback.

3.3 Curriculum implementation

To implement planetary health into the curriculum, decisions must be made regarding when and where in the program this integration should occur. If a single subject is shared across disciplines, each discipline should have the freedom to implement the subject in a manner that aligns with their professional needs. During pilot implementation and regardless of whether the mode of curriculum delivery is asynchronous or synchronous, virtual, hybrid or face-to-face, it is of value to build in evaluation processes that will run alongside the curriculum delivery. These evaluation processes can include learning platform analytics, built-in student feedback via surveys or open invitation to make constructive comments either anonymously or otherwise and setting up mechanisms for long-term follow ups on student career outcomes. It also requires teaching staff to reflect on the implementation process to decide on necessary adjustments to improve outcomes.

3.4 Curriculum evaluation

The process for curriculum evaluation should be established at the project's inception using education research-based frameworks such as Kirkpatrick-Barr Framework (87). This approach allows for detailed, prospective data collection during the curriculum's implementation, as well as longitudinal data on student outcomes and career choices, helping to refine curriculum content and delivery. The Curriculum Planning and Evaluation Committee can review these results and act as a source of further direction on curriculum development. Another opportunity for evaluation is curriculum benchmarking against set standards that can be developed in collaboration with other universities (88). Revised curriculum can then be implemented and reviewed on a regular basis. To achieve real transformation, a praxis for planetary health education has been proposed, which is influenced by Indigenous knowledge systems, critical theory, and an ethics of care (76) (Figure 4). This praxis is a convergence of compassion-knowledge-reflection that best enables the formation of planetary stewards. Utilizing this praxis when evaluating the implementation of planetary health education is both a process and outcome that advances social and environmental justice (76).

4 Conclusion

Integrating the Planetary Health Education Framework into health professional degrees is essential for addressing the interconnected challenges of human health and the triple planetary crisis of climate change, biodiversity loss and pollution. The work presented here draws on educators' experiences in overcoming barriers to equip future healthcare professionals with the knowledge and skills to reduce environmental health impacts and promote sustainable healthy lifestyles. Co-designing curriculum between students and educators shows great promise as an approach to increase both student engagement and educator capacity to facilitate planetary health education. To date, this often has been driven by planetary health champions, but top-down accreditation standards and bottom-up student demand for curriculum is accelerating. One limit to our work stems from the preponderance of literature reflecting experiences from the high-income counties. Yet, planetary health programs are growing globally, and new lessons will inevitably emerge from low-to-middle-income settings.

Incorporating an Indigenous lens enriches our proposed toolbox, as Indigenous knowledge systems provide critical insights into sustainable living and the interconnection of people and ecosystems. By learning from Indigenous perspectives, health professionals can develop culturally safe approaches that respect and incorporate Traditional Ecological Knowledges. However, it is in high-income countries that such integration needs improvement.

In summary, the proposed implementation toolbox must evolve with new perspectives, ever-advancing technology, and increasing

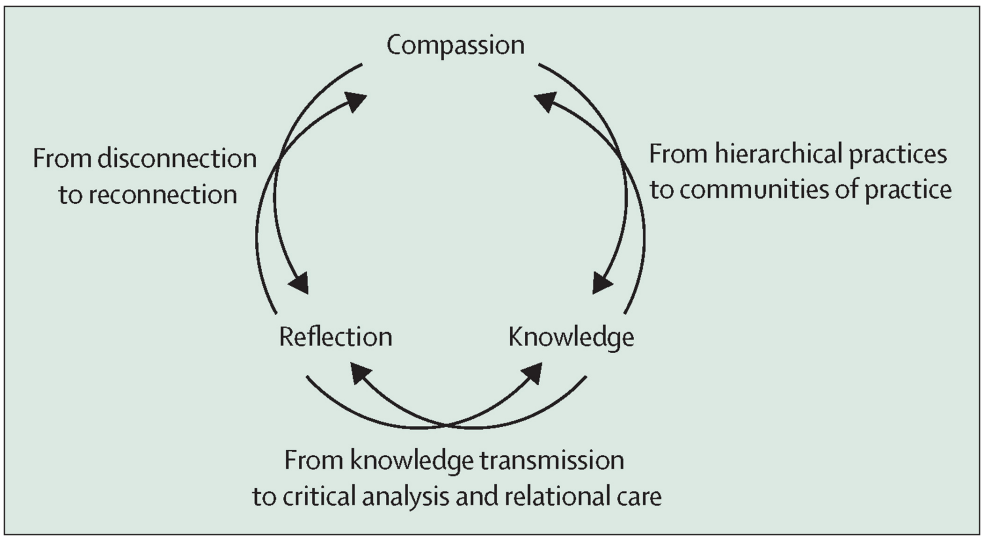

FIGURE 4
Reproduced from Redvers et al. (76) by permission of the authors.

resources considering the urgency of the triple planetary crisis. We offer a starting point for practical strategies and resources, ensuring systematic and iterative curriculum development, and allowing for continuous improvement and adaptation to changing needs for incorporating the planetary health into mainstream health education.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZL-T: Conceptualization, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. LB: Writing – original draft, Writing – review & editing. JLe: Writing – original draft, Writing – review & editing. JLu: Writing – original draft, Writing – review & editing. SM: Visualization, Writing – original draft, Writing – review & editing. VL: Writing – original draft, Writing – review & editing. PP: Writing – original draft, Writing – review & editing. MF: Writing – original draft, Writing – review & editing. MK: Writing – original draft, Writing – review & editing. KL: Writing – original draft, Writing – review & editing. JP: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Michelle McLean,
Bond University, Australia

REVIEWED BY
Rohini Roopnarine,
St. George's University, Grenada
Carlos A. Faerron Guzman,
University of Maryland, Baltimore,
United States

*CORRESPONDENCE
Eva-Maria Schwienhorst-Stich
✉ schwienhor_E@ukw.de

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Planetary health education in undergraduate medical education in Germany: results from structured interviews and an online survey within the national PlanetMedEd Project

Fabio Grieco[1], Sandra Parisi[1], Anne Simmenroth[1], Michael Eichinger[2,3], Janina Zirkel[1,4], Sarah König[5], Jana Jünger[6,7], Eva Geck[1] and Eva-Maria Schwienhorst-Stich[1]*

[1]Department of General Practice, University Hospital Würzburg, Würzburg, Germany, [2]Center for Preventive Medicine and Digital Health, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany, [3]Institute of Medical Biostatistics, Epidemiology and Informatics, University Medical Center of the Johannes Gutenberg University Mainz, Mainz, Germany, [4]Department of Internal Medicine II, University Hospital Würzburg, Würzburg, Germany, [5]Institute of Medical Teaching and Medical Education Research, University Hospital Würzburg, Würzburg, Germany, [6]CARES Institute, Heidelberg, Germany, [7]Faculty of Medicine, Heidelberg University, Heidelberg, Germany

Background: In light of the accumulating evidence, awareness and urgency to act upon the three planetary crises – climate change, biodiversity loss, and pollution – the concept of Planetary Health underscores their profound implications for health and promotes actionable solutions to advance both wellbeing and ecological sustainability. Despite (inter)national calls to integrate Planetary Health into health workers' curricula, the current status of Planetary Health Education in undergraduate medical education in Germany is unclear. This study therefore aimed (a) to assess the current implementation of Planetary Health in undergraduate medical education in Germany and (b) to explore its characteristics as a foundation to develop evidence-informed recommendations for mainstreaming Planetary Health Education in medical schools in Germany.

Methods: The study comprised structured interviews followed by an online survey, both targeting all 39 medical schools in Germany. In 2021, structured interviews were conducted with students, educators and deanery staff at medical schools. In 2023, educators and deanery staff participated in an online survey based on the findings from the interviews.

Findings: In total, 80% of the 39 medical schools participated in the interviews, while 90% took part in the online survey. Based on integrated findings, 35 medical schools (90%) offered Planetary Health Education, with a median of two educational activities, including both stand-alone courses and lectures integrated into other courses. Despite an overall increase since winter semester 2021/2022, most educational activities were electives and not part of the mandatory curriculum. Innovative educational approaches and learning objectives differed significantly between mandatory and elective formats. In contrast to mandatory educational activities, student involvement was reported for the majority of electives and was significantly associated with transformative learning objectives.

Interpretation: Despite a steady rise in teaching activities, mandatory Planetary Health Education remains insufficiently integrated into undergraduate medical education in Germany. Key criteria defining high-quality Planetary Health Education, such as innovative educational approaches, practical skills, and transformative learning, were primarily reflected in electives, that reach only a minority of students. To adequately equip the future healthcare workforce, the current barriers to successfully integrating Planetary Health into medical education must be systematically addressed and overcome.

KEYWORDS

Planetary Health, Planetary Health Education, One Health, climate change and health, health professions education, medical schools, curriculum development, education for sustainable healthcare

1 Introduction

Climate change and the transgression of other planetary boundaries, such as biodiversity loss, altered biogeochemical flows, and pollution, are the most important health threats in the twenty-first century (1, 2). Planetary Health (PH) is a solutions-oriented field that focuses on the interconnectedness of climate and ecological crises with societal, political, and economic systems, and their impacts on health and well-being (2).

Due to human activities, safe operating spaces have been crossed for six of the nine planetary boundaries, posing significant risks to life as we know it. Climate change, for instance, leads to an increase in heat-related deaths, particularly among vulnerable populations (3). Rising temperatures have a substantial impact on infectious disease patterns, facilitating the spread of vector-borne diseases. Air pollution, closely linked to the combustion of fossil fuels, not only has detrimental effects on respiratory tract diseases such as asthma and COPD, but also serves as a risk factor for cardiovascular and neuropsychiatric conditions (4).

The healthcare sector contributes to climate change, accounting for 4,4% of global greenhouse gas emissions (5). Combined with a rapidly changing burden of disease, this highlights the urgent need to implement sustainable healthcare solutions, and adapt healthcare systems to provide high-quality services for climate- and pollution-related diseases (5, 6). Healthcare workers, leveraging the trust placed in them, can serve as key agents of transformative action (6–8), both in adaptation and mitigation.

The concept of PH extends beyond the climate crisis to encompass other ecological crises. A holistic understanding of PH emphasizes interdisciplinarity, a deep connection with nature, and the inclusion of restorative, Indigenous, and intergenerational perspectives to broaden perspectives beyond an anthropocentric lens (9, 10). The concept of One Health, which promotes the health of humans, animals, and ecosystems—including marine ecosystems—is closely aligned with PH. In this work, we use PH as an inclusive framework that integrates diverse elements from these related concepts.

The need to train medical students in PH and sustainable healthcare by integrating transformative Planetary Health Education (PHE) – which includes education for sustainable health care (ESH) – into medical curricula is increasingly recognized by a growing number of stakeholders (6, 10–12). Despite this, a global survey from 2020 revealed that only 15% of medical schools had incorporated education on climate change and health into their curricula (10). Evidence on the current implementation of PHE and its characteristics remains sparse, primarily consisting of individual case reports (13, 14) or broad overviews (15–17). A structured approach to assess the implementation of PHE is the Planetary Health Report Card (PHRC) (18), a student-driven initiative aimed at evaluating PH activities in health professions' education. As of 2024, only eight report cards have been submitted for medical schools in Germany across all three annual data collection rounds, providing an incomplete overview of PHE in undergraduate medical education.

The *Lancet Countdown Policy Brief 2021 for Germany* underscored that PHE often relies on individual efforts rather than being institutionally embedded, and further emphasized the critical need to enhance data on PHE (12). The training gap is further reinforced by research suggesting that medical students are aware of the health effects of – in this case – climate change, yet perceive limited implications for their professional responsibilities (19, 20). Moreover, many students feel they receive insufficient training on these topics during their studies and express interest in expanding the integration of PHE in their education (19, 21).

PHE emphasizes Planetary Health literacy as a central educational goal, extending beyond the mere acquisition of knowledge to include values and transformative competencies (6, 8). Achieving this depth in PHE requires diverse didactic approaches that foster not only intellectual understanding but also ethical engagement and skill-based competencies (6, 8, 10). This alignment of educational approaches with different levels of Miller's competency framework – categorized as "Knows," "Knows how," "Shows," and "Does" (22) – is essential for developing effective PHE (8). While traditional lectures may suffice for foundational knowledge ("Knows," "Knows how"), they fall short in training higher-level competencies such as "Shows" and "Does," which require active student engagement. For these advanced competencies, hands-on and reflective educational approaches are essential, enabling learners to train practical skills, including communication, critical to Planetary Health advocacy and action (6–8, 10).

In Germany, the medical degree program spans six years, consisting of two pre-clinical years, three clinical years, and one year of practical training. The Medical Licensing Regulations (*Ärztliche Approbationsordnung*) specify all mandatory subjects in the standard curriculum (23). Planetary Health, however, is notably absent from this list of required subjects.

The content and objectives of medical curricula are outlined in the German National Competency-based Learning Objectives Catalog in

Medicine (*Nationaler Kompetenzbasierter Lernzielkatalog Medizin, NKLM*), first introduced in 2015 and currently being updated from Version 2.0 to 3.0 (24). The NKLM provides a comprehensive framework of learning objectives (LO) for each subject within the medical curriculum, offering guidance to medical schools, though it remains non-binding. Beyond the core curriculum, the current version (NKLM 2.0) includes several optional cross-cutting addenda, such as the Global and Planetary Health Addendum, which includes One Health and ESH approaches (25). While the addendum partially extends beyond the scope of core curricula, it nevertheless has the potential to guide educators in developing content for both mandatory and elective PHE. In addition to the core curriculum, medical students are required to complete electives from their institutions' portfolios. Electives provide educators with significant flexibility in curriculum design, often allowing new or emerging topics to be first introduced.

Consequently, PH topics can be integrated into undergraduate medical education by incorporating relevant aspects into existing educational activities (e.g., PH and cardiovascular/respiratory/women's/child/mental health) or by offering dedicated PH electives. So far, however, no studies have systematically assessed the prevalence or implementation of PHE within medical schools in Germany.

This study therefore aimed to (a) assess the current implementation of PHE in undergraduate medical education in Germany and (b) explore the characteristics of PHE, including educational approaches, learning objectives, interdisciplinarity and student involvement. The results of our study have the potential to guide the development and implementation of high-quality, transformative PHE initiatives, both in Germany and globally.

2 Materials and methods

2.1 Study design

The study presented in this paper is part of the national mixed-methods *Planetary Health in Medical Education (PlanetMedEd)* Project that aims to comprehensively assess the current state of PHE in medical schools in Germany, including the opportunities and barriers for its implementation in medical curricula (26). The PlanetMedEd Project includes quantitative studies using online surveys and quantitative interviews at medical schools, as well as qualitative interviews with students, educators and deanery staff (Supplementary material 1), which have already been published elsewhere (27, 28). To ensure consistent analysis of PHE across all studies within the PlanetMedEd Project, we developed a *Definition of Planetary Health Topics*, which was used in all studies (Table 2).

Our study employed a sequential design consisting of structured interviews followed by an online survey, both targeting all 39 medical schools that are members of the Association of Faculties of Medicine in Germany (Supplementary material 2). This did not include three newer, partially private medical schools.

In a first step, we conducted structured interviews to assess the existence of PHE activities offered during the winter semester of 2021/2022 or planned for the summer semester of 2022. Based on these findings, we developed an online survey to assess PHE activities offered during the winter semester of 2022/2023 or planned for the summer semester of 2023, as well as to explore their characteristics in detail. Data from both the interviews and the online survey were integrated to assess the current implementation of PHE (study objective a), whereas the online survey alone was used to explore detailed characteristics (study objective b; Figure 1). Complementary sampling strategies and data collection methods at two different time points were employed to provide a comprehensive overview of PHE. The use of investigator and data triangulation served to enhance the validity of our findings.

2.2 Participants and data

2.2.1 Structured interviews

Interview participants were identified in mid-2021 by screening the websites of all medical schools and leveraging existing networks in medical education and PHE in Germany. We invited members from all 39 medical schools in Germany and medical education networks to participate in the interviews. Three different groups (educators, deanery staff, students) were eligible to participate if they could give detailed information about a PHE activity at their respective medical school. Data were included in the study if they covered at least one learning objective from both Chapter 1.1 and Chapter 1.2 of the study's *Definition of Planetary Health Topics* (Table 2). These chapters refer to foundational knowledge about core areas of PH (e.g. anthropogenic environmental changes; interconnectedness of climate, other anthropogenic environmental changes and health). The guideline and items for the structured interviews were developed by the research team (Supplementary material 3). One researcher (EG) conducted the video interviews between June and September 2021 using Zoom Video Communications without recording. During the interview, this researcher entered the data into a standardized and pretested Microsoft Excel spreadsheet, sharing the screen with the interview partners. Following completion of all interviews, the spreadsheets were sent to the interview partners and the study deaneries of the respective medical school for member checking. In addition, two researchers (EG and EMSS) conducted comprehensive plausibility checks for data consistency.

2.2.2 Online survey

Based on the structured interview guide, we developed the questionnaire for the online survey (Supplementary material 4) between October and December 2022. It underwent qualitative pretesting among six students and quantitative pretesting among five medical doctors and members of the Department of General Practice at the University Hospital Würzburg, who were involved in PHE or experienced in questionnaire development.

The questionnaire was administered in German and covered the following information:

- General information about the medical school
- Characteristics of the educational activity, including learning objectives, teaching and assessment methods
- Cooperation with other educators or students
- Faculty support for Planetary Health

Each participant could report one or two PHE activities per survey completion. For reporting one activity, the questionnaire included 11 open-ended questions and 38 quantitative items, seven of which were mandatory. Reporting a second activity required

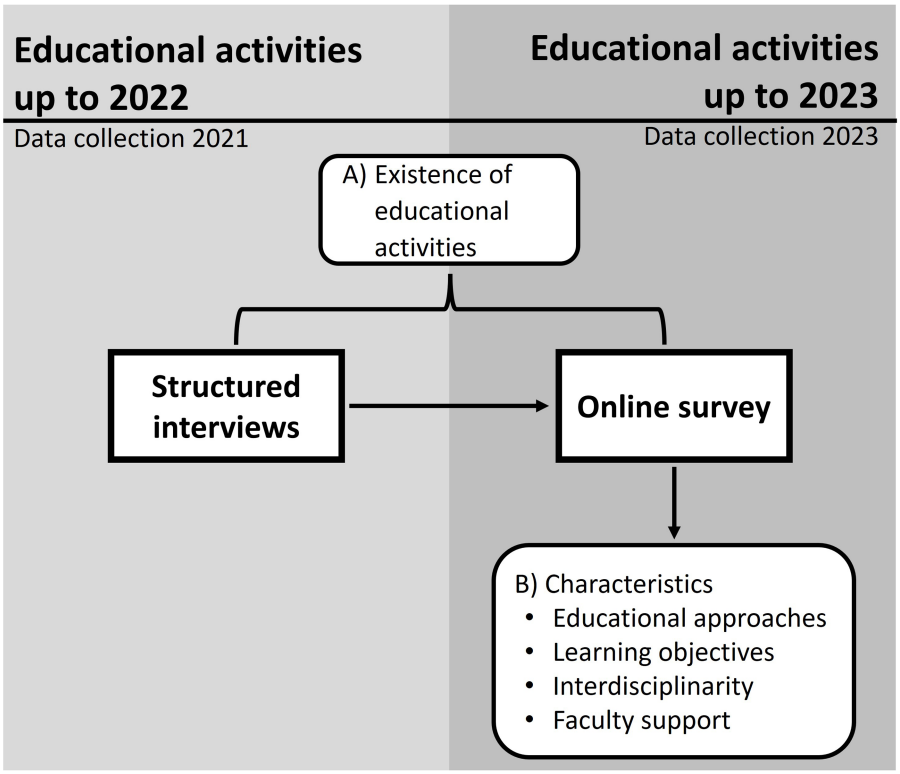

FIGURE 1
Study design and triangulation of different data sources.

answering additional six open-ended questions and 30 quantitative items. Participants wishing to fill in more than two educational activities were instructed to restart the survey. In medical schools without PHE, participants were asked five mandatory quantitative items and three open-ended questions. Teaching methods were assessed semiquantitatively using percentage ranges. The survey was implemented in EvaSys (Evasys Survey Automatic Suite, Version 8.0).

The questionnaire was sent to five different groups (Supplementary material 5) in January 2023: (1) The deans of study or study deaneries of all 39 medical schools in Germany and (2) the student councils were contacted via the official email addresses obtained from their respective websites. (3) Local groups affiliated with the *Health For Future (HFF)* movement were identified on the HFF website in 37 cities with medical schools and contacted. (4) To expand outreach through snowball-sampling, invitations were extended to networks including HFF, the *German Climate Change and Health Alliance* (*KLUG e.V.*), and the German *Master of Medical Education*. (5) Participants of the previous structured interviews were also invited to participate in the online survey or to forward the invitation. A first reminder was sent in February 2023, followed by a second reminder in March 2023 to contacts at medical schools that had not yet provided data by then. This sampling strategy aimed to ensure standardized outreach to all 39 medical schools while simultaneously maximizing response rates.

In the structured interviews, students were among the eligible participants. In contrast, the online survey focused on educators and members of (study) deaneries to obtain more detailed data on the educational activities. Students were only eligible if they were actively involved in the PHE activity. All others were encouraged to forward the invitation to eligible participants. For inclusion in the analysis, submitted activities had to cover at least one learning objective of both Chapter 1.1 and Chapter 1.2 of the updated version of our *Definition of Planetary Health Topics* (Table 2).

If participants' answers did not meet these criteria, two researchers (FG and EMSS) independently assessed those survey responses for eligibility. Any discrepancies were resolved through discussion. Surveys were also screened for duplicate information. Additionally, all data underwent a thorough check for plausibility, with inconsistent entries reviewed by two researchers (FG and EMSS).

2.3 Data analysis

Data analysis was performed using IBM SPSS Statistics (Version 27, IBM Corp). Descriptive analyses were conducted for both aspects of the study. Associations between categorical variables in the online survey were assessed with Chi-square tests or Fisher's exact tests in case of small sample sizes. For significant associations, Cramer's V was calculated. Associations between research activity and the number of educational activities were investigated using Mann–Whitney-U-tests due to non-normal distribution of the data. Statistical analysis included only courses where corresponding questions were answered yes or no (not unknown).

When qualitative information regarding teaching or assessment methods was provided in the open-ended survey questions that corresponded with quantitative items ("if other, please specify"), it was incorporated in the quantitative analysis. No thematic analysis was performed, as only very limited further information was provided in the open-ended questions. Qualitative data pertaining to the institutional background of the participants was categorized based on curricular subjects defined in the Medical Licensing Regulations.

During data collection, we attempted to distinguish between *courses* defined as stand-alone PHE activities and *classes* defined as PH teaching integrated into other courses. However, this classification proved unhelpful for addressing the main research questions and was not clearly differentiated by the study participants. Consequently, we chose to summarize both stand-alone PH courses and PH teaching sessions incorporated into other courses using the term *educational activities*. They were further categorized based on the number of course units (CU) and stratified by whether they were mandatory or elective.

2.4 Ethical considerations

Both the interview study and the online survey received approval by the ethics committee of the University of Würzburg (20210312-01 and 20231123-01). All participants received detailed information about content and conduct of the study as well as data protection measures. The interviewees provided written informed consent to participate in the interviews, which were not recorded. Written informed consent was not required for the survey as only anonymous data were collected.

3 Results

In total, 50 individuals participated in the structured interviews, after they had confirmed that their educational activities met the inclusion criteria. In the online survey, 71 individuals entered data, with 66 meeting the inclusion criteria. For six submitted activities, the required learning objectives as inclusion criteria were not reported or marked *unknown*. After thorough evaluation by two researchers (FG and EMSS), three of those were included in the study, based on other clear indicators of PHE, while the remaining three were excluded.

3.1 Existence of educational activities

One hundred and thirty-eight different PHE activities were identified: 60 exclusively through interviews and 43 exclusively through the online survey, 35 of the 138 activities were reported in both. Among medical schools offering PHE, 90% in the interviews and 100% in the online survey offered at least one elective activity. Mandatory activities were offered by 65% of medical schools in the interviews and 40% in the online survey. Triangulated data from both the structured interviews and the online survey are presented in Table 1 and Figure 2. Both the interviews and the online survey indicated an increase in PHE activities with the largest absolute increase observed in the winter semester 2021/2022 (Figure 2).

3.2 Characteristics of educational activities

In total, 78 activities from the online survey were included in the analyses of detailed characteristics. Few activities lacking specific information for a particular question were excluded from the analysis pertaining to that question, as shown by the indicated n for the respective question.

The number of participants varied, ranging from ≤10 to >101, with a median of >101 participants for mandatory and 11–20 participants for elective activities. Educational approaches differed between mandatory and elective activities as illustrated in Figures 3A and 3B. Mandatory activities predominantly used lectures as a teaching method and employed multiple choice quizzes (MCQ) or open-ended-text exams as assessment methods. Electives used a more varied set of teaching and assessment methods aiming at upper Miller competency levels ("Shows How," "Does") such as simulation, skills training for communication (STC) or small group work as teaching methods and final reflection or project work as assessment methods.

Most learning objectives (LO) were reported more frequently for elective as compared to mandatory educational activities (Table 2). Notably, LOs related to transformative competencies (Chapter 3) were significantly more emphasized in elective activities than in mandatory ones.

Student initiatives or partners from other disciplines were involved in 32 activities. Almost a quarter (n = 18) were open to non-medical students within the medical school or other faculties. Student involvement and collaboration with other partners were more frequent in electives (Figure 3C). When student initiatives were involved, they were actively engaged in initiating (72%), planning, or implementing (both 75%). Educational activities involving student initiatives aimed at transformative LOs (Chapter 3) significantly more often than those without student involvement (100% vs. 74%, n = 65, p = 0.002, Cramer's-V = 0.38). As transformative LOs were predominantly covered in electives, these were analyzed separately to mitigate potential confounding. In the stratified analysis, transformative LOs were significantly more often covered in electives with student involvement (p = 0.04, Cramer's-V = 0.35). No significant differences were found for LOs from Chapter 1.3 and Chapter 2 of the *Definition of Planetary Health Topics*.

Research focused on PH was reported for 19 medical schools, accounting for 54% of the participating and 49% of all medical schools in Germany. Among others, this included a chair for climate change and health and different working groups with a focus on PH, for example at departments for hygiene, infectious diseases or general practice. Medical schools without research activity on PH reported a median of one PHE activity, whereas those with such research activity reported a median of three. This difference was statistically significant (U = 56.5, Z = −2.38, p = 0.009). Participants who submitted at least one activity, were also asked about the presence of a dedicated PHE coordinator at their medical school, which was reported by eight schools.

TABLE 1 Side-by-side display of integrated findings from structured interviews and the online survey, 1 CU = 45 min.

	Structured interviews	Online survey
Contacted medical schools	39	39
Data collection	June–September 2021	January–March 2023
Participating medical schools	31	35
Medical schools that submitted at least one PHE activity	31	30
Integrated findings 1: Interviews and online survey had high response rates. The majority of medical schools in Germany offered at least one Planetary Health educational activity each		
Participants, of which were:	50	66
(Study) deanery	1	9
Students	24	6
Educators (teaching discipline below)[a]	25	51
General practice	..	15
Interdisciplinary subjects[b]	..	11
Occupational medicine	..	6
Internal medicine	..	4
Preclinical subjects	..	3
Pediatrics	..	3
Infectious diseases	..	2
Psychiatry	..	2
Hygiene, microbiology, virology	..	1
Pharmacology, toxicology	..	1
Medical education	..	1
Medical history, theory, ethics	..	1
No answer	..	1
Integrated findings 2: Students and educators participated almost equally frequent in the interviews. The online survey primarily targeted educators from diverse professional backgrounds to investigate more education characteristics in-depth		
Activities identified only in this study part	60	43
Activities identified in both study parts	35	35
Total number of submitted activities	95	78
Median number per medical school	2	2
Range per medical school	1–9	1–8
Mandatory vs. elective educational activities	$n = 95$	$n = 78$
Mandatory	32 (34%)	24 (31%)
Elective	63 (66%)	54 (69%)
Integrated findings 3: A median of two activities per medical school was identified. The majority of reported activities were not mandatory, but elective activities catering to a limited proportion of students		
Course units (CU): Mandatory	$n = 27$	$n = 24$
Median	2 CU	2 CU
Range	1–7 CU	1–8 CU
Course units (CU): Elective	$n = 40$	$n = 53$
Median	9 CU	16 CU
Range	1–45 CU	1 – over 60 CU
Integrated findings 4: Mandatory educational activities reported were typically single lessons (2 CU = 90 min), while electives generally comprised more course units		

Data of the structured interviews includes data retrieved from one written feedback by a deanery. [a]Data about the field were only obtained in the online survey. [b]Interdisciplinary subjects: include participants from institutes whose teaching is part of the interdisciplinary subjects as defined by the Medical Licensing Regulations (1: epidemiology, medical biometry, and health informatics. 3: health economics, health system and public health. 6: clinical environmental medicine. 10: prevention and health promotion). CU, course unit; PH, planetary health.

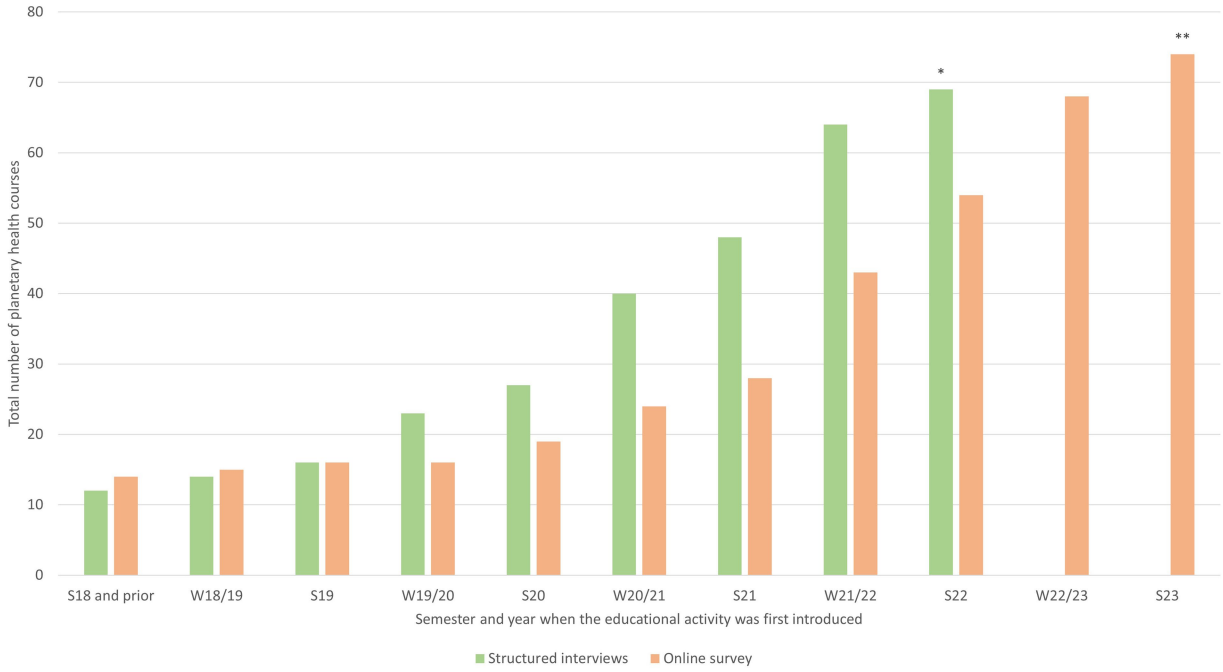

FIGURE 2
Semester when educational activity was first introduced. *n* = 69 (interviews)/74 (online survey), missing: 26 (interviews)/4 (online survey), *new activities planned for summer semester 2022 (from structured interviews), **new activities planned for summer semester 2023 (from online survey). S, summer semester; W, winter semester.

4 Discussion

To our knowledge, this is the first nationwide study to thoroughly investigate the current implementation and characteristics of PHE in undergraduate medical education across all medical schools with this level of detailed overview of educational approaches, learning objectives, student involvement and interdisciplinarity. Our study holds transformative potential as suggested by previous research on PHE (17). High response rates of 80 and 90% of medical schools in the interviews and the online survey, respectively, provide a solid foundation for a granular assessment of PHE in Germany, highlighting opportunities for curriculum innovation in light of the Ten Characteristics of High-quality PHE developed in a companion study of the PlanetMedEd Project (hereinafter referred to as Ten Characteristics) (27).

4.1 Existence of educational activities

Only 35 of all 138 activities were reported in both interviews and the online survey, with the majority appearing only in one of the two. This highlights the value of combining different research methods to obtain a comprehensive overview. We observed a continuous increase in PHE activities since 2019. Educators from diverse professional backgrounds contributed data to the study, indicating the involvement of multiple disciplines in PHE.

Most medical schools offered at least one PHE activity. Only one-third of all activities, however, were mandatory, highlighting the need for greater curricular integration (27). Education predominantly offered in elective format risks reaching only students already interested in the field. Moreover, integrating PHE into existing mandatory education appears to be preferred by students (29), suggesting potential for strong coalitions with educators aiming to strengthen PHE. With a median of two course units, mandatory educational activities mainly seemed to follow a single-session approach, limiting the coverage of complex PH topics that go beyond an introduction to the field (30).

4.2 Characteristics of educational activities

PHE requires transformative educational methods (6, 31). Lectures, however, were still the predominant teaching method in both elective and mandatory activities. Innovative educational approaches including problem based learning (PBL), simulations, skills training, and peer teaching were more common in electives. These therefore addressed the need for transformative educational methods in PHE more comprehensively (6, 31). Assessment methods targeting higher levels of Miller's competency framework (22), such as project work, final reflections, or presentations were also reported more frequently for elective educational activities. Objective Structured Clinical Examinations (OSCE) were almost non-existent, despite recent research indicating their importance in PHE (13). Thus, we found different "innovative and proven didactic methods," from the Ten Characteristics (27) mainly in electives. Combining different innovative educational approaches seems most appropriate to address the complexity of PHE (27, 30) and may contribute to better learning outcomes (32).

Knowledge, values and competencies – key areas of PHE (6, 8) – reflected in Chapters 1–3 of our *Definition of Planetary Health*

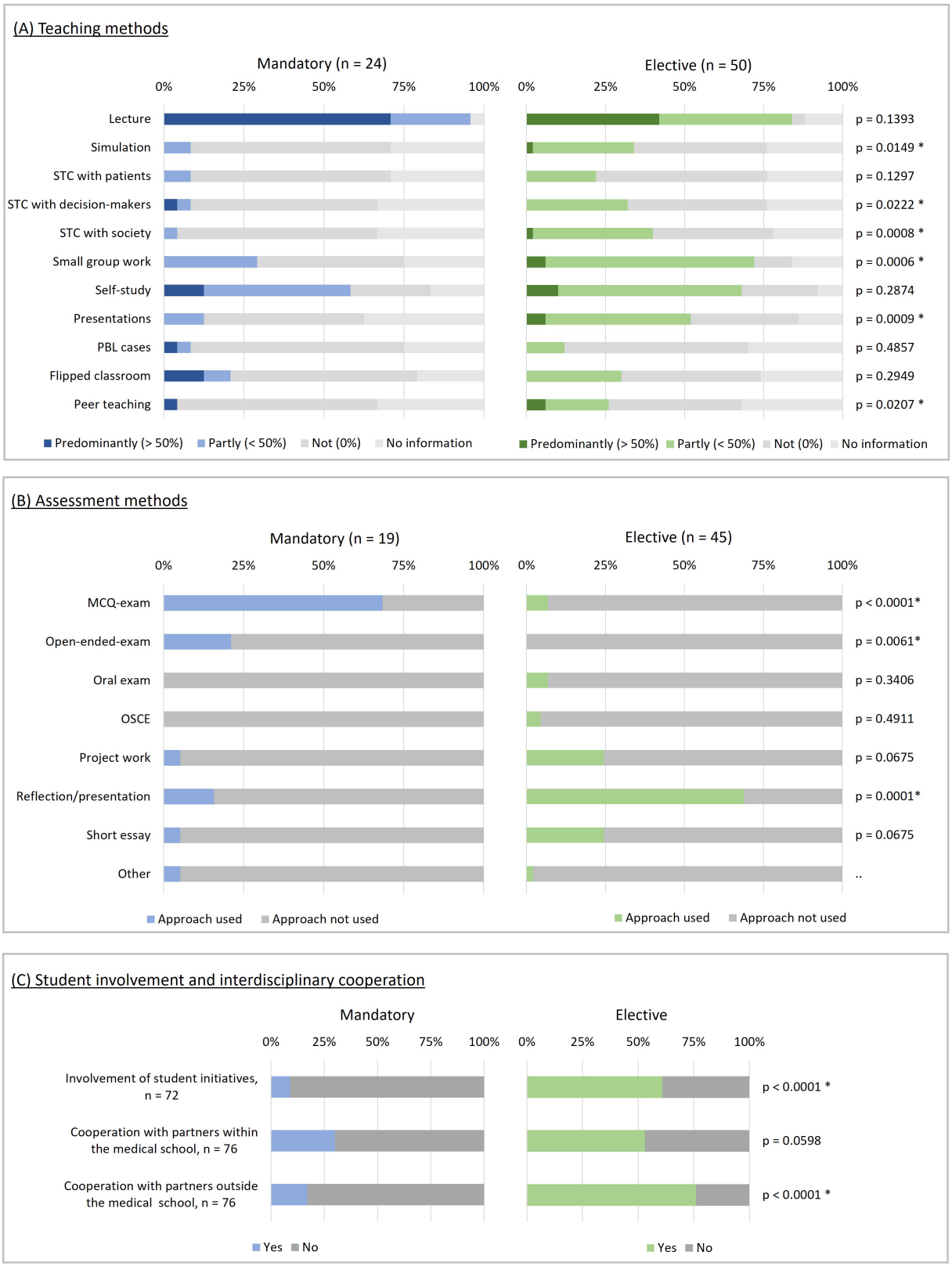

FIGURE 3
Characteristics of educational activities. Left: Mandatory, right: elective, multiple selection possible, * $p < 0.05$. **(A)** Teaching methods, PBL, problem-based learning; STC, skills training for communication. **(B)** Assessment methods, MCQ, multiple choice quiz; OSCE, objective structured clinical examination. **(C)** Student involvement and interdisciplinary cooperation.

TABLE 2 Learning objectives addressed in mandatory and elective educational activities, multiple selection possible.

Learning objective (LO)	Mandatory educational activities	Elective educational activities
	Percentages represent the proportion of activities reporting this LO among all activities with available data on the respective chapter	
Chapter 1. Graduates demonstrate foundational knowledge about core areas of Planetary Health. They demonstrate understanding of associations regarding the following topics:		
1.1: Anthropogenic environmental changes, e.g.: (n = 76: 22 mandatory, 54 elective), (= inclusion criteria)		
Climate change	75%	98%
Other environmental changes	38%	59%
Planetary boundaries	50%	85%
Systems research	42%	67%
At least one of these LO	100%	100%
Chapter 1.2: Interconnectedness of climate, other anthropogenic environmental changes and health, e.g.: (n = 77: 24 mandatory, 53 elective), (= inclusion criteria)		
Heat	79%	92%
Other extreme weather events	46%	58%
Infectious diseases	50%	75%
Toxin-mediated diseases	21%	34%
Cardiovascular diseases	46%	60%
Endocrinological diseases[a]	21%	21%
Oncological diseases[a]	17%	26%
Allergies	54%	74%
Maternal and child health	21%	47%
Neurological diseases	13%	15%
Mental health	42%	70%
Migration and violent conflicts	38%	53%
Connections of nutrition, environment and health	38%	79%
Co-benefits[b]	42%	74%
At least one of these LO	100%	100%
Chapter 1.3: Populations that are particularly affected by global environmental changes and their vulnerability factors (n = 69: 21 mandatory, 48 elective) For example: Children, infants, elderly, people requiring care, (pregnant) women, people with pre-existing conditions, polypharmacy, pre-existing psychological vulnerability, low socio-economic status, precarious living/working conditions, migration background, populations in regions without sufficient social security systems, climate justice (incl. global and local discrepancy between those responsible and those affected)		
At least one of these LO (p = 0.1609)	86%	96%
Chapter 2: Graduates reflect on their responsibility to establish, maintain and foster human health and the natural and social systems on which it depends (n = 73: 22 mandatory, 51 elective) For example: sustainable transformation of all relevant areas of society including mobility, nutrition, energy, agriculture, consumption, economy, healthcare, social and legal norms		
At least one of these LO (p = 0.4094)	95%	90%
Chapter 3: Graduates describe and demonstrate skills to stimulate and implement transformative change. They know concrete examples of transformative action and can implement measures themselves, e.g.: (n = 70: 21 mandatory, 49 elective)		
Climate communication	43%	73%
Science communication	5%	41%
Transdisciplinary collaboration	24%	65%
Project management	5%	33%
Sustainable healthcare	57%	88%
Working with heat action plans	19%	41%
None	29%	6%
At least one of these LO (p = 0.0176*, Cramer's V: 0.3073)	71%	94%

LO, learning objective. *Statistically significant differences: $p < 0.05$. [a]These LOs were added to this table after constructive feedback for the online survey and were not part of the definition during the structured interviews. [b]This LO was moved from Chapter 3 to Chapter 1.2 to introduce co-benefits on a knowledge level. During the structured interviews, it was still listed under Chapter 3. This list of learning objectives reflects the definition of Planetary Health used within the PlanetMedEd Project as previously published (28). It was based on the German National Competency-based Learning Objectives Catalog in Medicine (NKLM 2.0), specifically on the optional addendum Planetary and Global Health (25).

Topics (Table 2) were addressed to varying extents. All educational activities addressed LOs related to knowledge, although the depth of coverage varied (Chapter 1). Comprehensive integration of PHE into medical curricula, however, requires broad coverage of all relevant topics, including the "responsibility of health professionals" and "transformative competencies" (27). LOs related to responsibility (Chapter 2) were covered in nearly all educational activities, while transformative competencies (Chapter 3) were primarily addressed in elective courses. The broader scope of learning objectives covered in electives may reflect the higher number of course units in these courses. To fully leverage the potential of PHE, educators should place greater emphasis on integrating content that strengthens transformative competencies of students.

Partnership with students can enrich PHE (6) and is described as an important quality characteristic (27). In our study, student involvement in teaching activities was predominantly reported for electives and was significantly associated with transformative learning objectives in our study, underscoring the crucial role of students in PHE. Despite the recognized importance of inter- and transdisciplinarity in PHE (6, 27), interdisciplinary collaborations with academic partners, both within and outside the medical school, were reported for only about half of the educational activities assessed, with electives being particularly prominent. Teaching methods with the potential to advance transdisciplinarity, such as skills training for communication with the general public, were almost exclusively reported for electives.

4.3 Guiding Planetary Health Education

Research focused on PH was reported for approximately half of the medical schools. Detailed questions about the structure and content of research activities were not included in this study, as the focus was on educational activities. The positive association between PH research and the number of PHE activities suggests that research may play a key role in driving the integration of PHE into medical curricula. Potential underlying mechanisms for this association include increased awareness, broader faculty support, or the availability of experts capable of delivering dedicated PH teaching.

PHE coordinators could help address key barriers to the inclusion of PHE in medical curricula, such as lack of faculty support, time, expertise or confidence (30). Given that PHE coordinators were reported in only eight medical schools, establishing coordinators should be considered a priority for the development of PHE.

The lack of academic requirements and binding standards for PHE (30), including the non-mandatory PH addendum to the National Competency-based Learning Objectives Catalog in Medicine (25), hinders curriculum innovation in Germany and may contribute to the heterogeneous implementation of PHE observed in this study. These findings emphasize the need for comprehensive integration of PH content into mandatory curricula through an intersectional approach. PH aspects should be incorporated into various subjects, their assessments, and the state exams for the medical degree. Additionally, elective courses offer opportunities to provide more tailored and more comprehensive content for students particularly interested in PH (33). Our *Definition of Planetary Health Topics* (Table 2) outlines numerous opportunities to integrate PH across different subjects. At the same time, multiplier training within medical education networks could enhance the didactic skills of educators. Established elective courses can guide curriculum innovation as best practice examples, often meeting criteria for high-quality PHE (27). Consensus recommendations developed by medical associations, based on published learning objectives, can support efforts to mainstream PHE in undergraduate medical education (25) and help to increase the significance that educators attribute to PH, a known lever for successful PHE implementation (30).

4.4 Limitations

Several factors potentially limit the comprehensiveness of the PHE overview presented in this study. First, the sampling strategy involving PH networks may introduce selection bias. To attenuate this bias, we also invited the (study) deaneries of all 39 medical schools. Second, educational activities consisting of only one course unit might be underrepresented, as these activities are often not included in syllabi and related official documents. We aimed to reduce underreporting by combining structured interviews with an online survey and involved students, educators and study deaneries. Third, given the study's focus on PH stand-alone courses or entire PH sessions, PH content integrated into established educational formats at a micro level (e.g., integration of one slide focused on PH) was not captured. Fourth, as many study participants represented their medical school in an official capacity, social desirability bias might have induced an overestimation of addressed learning objectives and PH content. We anticipate that the interview study had a greater impact in this regard compared to the anonymous online survey. Fifth, as the study team was based in the general practice department, there may be an overrepresentation of educational activities related to general practice due to selection bias. Finally, underreporting might have occurred because the survey completion time amounted to approximately 15 minutes for one educational activity and 25 minutes for two. The comprehensive nature of our questionnaire, however, allowed us to explore various aspects of teaching activities in detail.

5 Conclusion

Our findings bridge the gap between numerous calls for action and frameworks for PHE and the lack of a comprehensive overview of PHE for the 39 assessed medical schools in Germany. While many medical schools now offer PH elective courses, comprehensive mandatory educational activities meeting standards for high-quality PHE remain scarce. Amidst ongoing and future reforms of medical curricula, well-established elective courses can serve as best-practice examples to guide the broader integration of PHE. This study can serve as a blueprint for monitoring curriculum innovation in Germany and internationally, advocating for the integration of additional PHE content by highlighting both the current state and existing implementation gaps in curricular PHE.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

FG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing. SP: Methodology, Writing – original draft, Writing – review & editing. AS: Methodology, Writing – original draft, Writing – review & editing, Conceptualization, Supervision. ME: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. JZ: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. SK: Methodology, Writing – original draft, Writing – review & editing. JJ: Writing – original draft, Writing – review & editing, Conceptualization, Methodology. EG: Methodology, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Investigation. E-MS-S: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Conceptualization, Project administration, Resources, Supervision, Validation, Visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2024.1507515/full#supplementary-material

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EDITED BY
Lynn Valerie Monrouxe,
The University of Sydney, Australia

REVIEWED BY
Alison Mostyn,
University of Nottingham, United Kingdom
Dana Perniu,
Transilvania University of Braşov, Romania
Hoo Tiang Boon,
Nanyang Technological University, Singapore

*CORRESPONDENCE
Nara Jones
✉ nara.jones@newcastle.edu.au

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Pedagogical strategies for supporting learning and student well-being in environmentally sustainable healthcare

Nara Jones[1,2]*, Graeme Horton[1], Michelle Guppy[3], Georgia Brown[1] and John Boulton[1]

[1]School of Medicine and Public Health, University of Newcastle, Newcastle, NSW, Australia, [2]School of Medicine, University of Tasmania, Hobart, TAS, Australia, [3]School of Rural Medicine, University of New England, Armidale, NSW, Australia

Planetary health education needs fresh approaches to engage learners and educators in positive visions and future planning to navigate the societal challenges of climate change. The human health impacts of the climate crisis, environmental degradation and pollution are far-reaching and compounding in nature. International leaders in healthcare are recognizing the time-pressured opportunity to mobilize and motivate colleagues to optimize health outcomes by addressing these issues. Healthcare systems across the globe contribute significantly to ecological footprints through greenhouse gas emissions and consumption of various polluting materials. Therefore, the necessity to prepare future health professionals to identify and manage environmental health conditions in their patients, as well as foster their future role as leaders and advocates in sustainable healthcare is acute. Health education organizations have begun to appreciate this need and have developed learning objectives to guide curricula. In the development and implementation of content on environmentally sustainable healthcare, an important consideration is the affective and moral distress from the confronting and often overwhelming nature of the topic. The main objective in teaching planetary health is to equip learners with the tools and skills to address the relevant health issues in their professional role whilst providing the support necessary for them to accept these harsh realities. The University of Newcastle and University of New England Joint Medical Program's, four-week course in Sustainable Healthcare aims to meet this objective. In this article we discuss how our curriculum utilizes Self-Determination Theory (SDT) and other psychological strategies to support learners' well-being and motivation. SDT explains the need for supporting autonomy, relatedness and competence in the learning environment. Strategies employed to address these include providing students with the opportunity to select discussion topics that they contribute to, maximizing choice of focus for the assessment task, utilizing personal reflections, case-based learning scenarios and incorporating presentations from relatable industry leaders.

KEYWORDS

planetary health, health professional education, sustainable healthcare, educational theory, student well-being

1 Introduction

As medical students are at risk of emotional distress when they learn about the effects of climate change on individual and population health, their well-being must be seen as a priority in order for them to maintain their motivation to engage with the subject. This is also critical for their understanding that their future professional involvement needs to be guided by moral values. Human health has long been recognized to be dependent on healthy and intact ecosystems, but the environmental determinants of health are now changing in unprecedent ways and rates. Planetary health has emerged in the wake of global events and encompasses climate change, biodiversity loss, pollution and the need for humans to live, work and to maintain their health in ways that do not compromise the ability of future generations to do the same (1).

In order to be fit for purpose as future doctors, medical students need to learn about the changing environmental determinants of health, understand the health impacts of planetary degradation and how to mitigate risk to their patients, practice in a sustainable way and advocate for reducing the environmental impact of the health care system (2). The addition of curricula to prepare medical students for managing the impacts of climate change or how to practice in an environmentally sustainable way is relatively recent. In 2019 an international survey of medical students identified that only 15% of medical schools had begun to include climate change and health into their curriculum (3). In recent years health professional education stakeholders have proposed learning objectives (4) and recommendations to assist in developing planetary health curricula (2, 5, 6). Whilst a number of programs have begun to implement and evaluate curricular interventions in this area (7–17), there has been little consideration as to which educational approaches support student well-being. Climate change is now causing widespread illness, injury and death from direct effects such as extreme weather events and sea level rise, and indirect causes such as crop failure, civil unrest and population displacement (18, 19). Further worsening impacts from climate change are unavoidable, and the likelihood of societal collapse and widespread suffering is increasingly described in the literature (20). The scale of the challenge of working to ensure that humanity lives within the capacity of the planet is such that students can feel overburdened. Uncomfortable feelings in learners can arise as they grapple with complex real-world problems entrenched in politics, exploitation, social disadvantage, and power imbalances (2).

Eco-anxiety, climate change distress and solastalgia are terms to describe negative emotions that relate to concern about the future, the loss that has already occurred, and the adverse consequences of human impact on the environment (21, 22). The psychological response to environmental degradation encompasses a wide range of emotions, especially in the younger generations. In their international study that surveyed young people from ten different countries on climate change distress, Hickman et al. found that of the 10,000 participants, over 50% reported feeling anxious, angry, sad, afraid, powerless, helpless and guilty (21). Furthermore, over 45% of participants felt that their feelings negatively impacted their daily life (21). These emotions originate not only from the concerns of the devastating impacts of environmental degradation, but also from the perceived lack of influence to tackle the enormous task ahead. The majority of power, when it comes to preventing and mitigating the impacts of threats to the planet, is held by governments, dominant industries and large corporations. Not only do individuals perceive they have little influence over these bodies, but there is also a sense that these entities are not adequately addressing the issues at hand. The Hickman et al. study also found that only 30% felt that their governments were taking their concerns about climate change seriously and 58% they felt their governments were betraying them and/or future generations (21). While this international study is the largest quantitative study contributing data to our understanding of emotional distress in young people related to environmental degradation, surveys of young people in Australia and the UK have demonstrated that significant proportions, 89% and 74%, respectively, of young people are worried about the effects of climate change (23, 24). A recent study of over 15,000 young people in the US demonstrated that 85% of participants were at least moderately worried about climate change and it's potential impacts (25). There is also significant concern raised by academics and health professionals regarding the direct and indirect effects on the psychological well-being of young people (26–31). Furthermore, the significant increase in youth led climate activism globally demonstrates the level of concern for the future amongst our youth (29). While the psychological impact of learning about sustainable healthcare on medical students has not been specifically investigated, students within studies evaluating a sustainable healthcare curricula intervention have described learning about climate degradation and the effects on patients as "scary", highlighting the importance of curricular to create a sense of empowerment to balance the potential distress and reduce the chance of becoming "disillusioned" or "disengaged" (10, 32). Educational stakeholders have recognized that we have a responsibility to consider student well-being and cultivate resilience for learning about this potentially confronting and "sobering" topic (33) and dealing with planetary health related uncertainty (2).

There is much to be gained by educators utilizing psychological theories that optimize human motivation for planetary health education. Implementing learning strategies underpinned by psychology enables knowledge acquisition, while supporting students to develop adaptive coping strategies and capacity to enact change in the face of uncertainty.

2 Pedagogical frameworks

Compared to when many of today's educators may have learned about motivation in the last decades of the previous century, we now better understand the basic psychological needs of people which if catered to, can provide conditions for optimal performance, creative problem-solving and conceptual learning (34). Faced with current and future planetary health challenges, professionals need to be optimally motivated and engaged. Self-determination theory, as developed by Deci and Ryan, explains that better outcomes result when a person is autonomously motivated, rather than controlled or incentivized contingent on performance. In other words, there are different types of motivation, and when people are intrinsically interested in an

activity, or personally identify the value of doing it, then they will be more energized and effective than if they feel or are forced into doing something, whether due to obtaining rewards and approval or to avoid shame or punishment (35). Social contexts, including educational settings, can support these natural tendencies or thwart them. The provision of the deep needs of people for autonomy, competence, and relatedness allows optimal human flourishing. Autonomy is the need to self-regulate one's experiences; a sense of voluntariness as distinct from independence. A hallmark of autonomy is that one's behaviors are self-endorsed. Competence refers to the need to feel effective and feel mastery when completing tasks. Relatedness is to feel socially connected, feel cared for by others, and contribute to others.

If these needs are satisfied, people are more likely to develop and function effectively and experience wellness. If these needs are thwarted, people will more likely evidence ill-being and non-optimal functioning. Classroom studies have shown that provision of autonomy to students by both teachers and parents has helped students maintain intrinsic motivation (36). Autonomously motivated learning has been found to lead to better educational outcomes, and medical students who have had autonomy-supportive learning have been shown to provide patient care that is more autonomy supportive (37).

Optimizing motivation is part of what is required in delivering planetary health education, but equipping learners with the emotional tools to manage the knowledge that they acquire is just as important. Climate change distress may be eased with judicious use of adaptive coping. Seth and colleagues have helpfully explained that such strategies comprise:

- Emotion-focused coping which addresses the feelings associated with climate change.
- Problem-focused coping which leads to behavioral responses.
- Meaning-focused coping that builds on hope and one's values (38).

The Australian Psychological Society outlines examples of adaptive coping strategies in their "Coping with change distress" resource. These include: taking a break from the 24/7 news cycle, taking specific action that is within one's own control to reduce their own carbon footprint, and prioritizing issues that are the most important, recognizing that no-one can do everything (39).

A third theoretical framework that is applicable to this area concerns taking action that is based on what is important to us. Acceptance and Commitment Therapy (ACT) has been identified as particularly suited to climate change distress with confronting concepts that cannot be refuted, highlighting the benefits of values-guided action. ACT provides guidance on how to reduce the impact and consequences of uncomfortable feelings and thoughts while planning actions to build a rich and meaningful life (40). While ACT is designed for clinical application, educators can apply some of these principles in guiding students to consider what is important and meaningful to them, and then to use these values to develop plans for actions that will enrich and enhance their lives and the world around them.

3 Learning environment

To demonstrate how principles of adaptive coping, self-determination theory and values-based action can be applied in planetary health curricula, we will describe the development of the sustainable healthcare course of the Joint Medical Program of the University of Newcastle and the University of New England (JMP). This course has been based upon the learning objectives of the Medical Deans Australia and New Zealand (MDANZ) Working Group on climate change and health. In 2017, a group of educators came together to develop learning objectives which were distributed to all medical programs in Australia and New Zealand as a resource that could be used to incorporate planetary health learning objectives in their curricula (41). The learning objectives were also published in the Medical Journal of Australia (4). The specific learning objects for the JMP course can be found in Table 1.

The four-week sustainable healthcare course commenced in 2021 as core learning for Year 3 of the JMP. The JMP is a 5-year program, of which the first two years are primarily classroom based and include a brief two-day General Practice (GP) placement. Year 3 of the program includes GP, hospital and classroom-based rotations. The sustainable healthcare course is conducted several times per academic year, with approximately one eighth of the student cohort completing their course at any one point. Therefore, students' prior exposure to clinical placements varies depending on when in the year their sustainable healthcare course occurs. A breakdown of JMP Cohort Demographics can be found in Table 2.

In developing the content, we were cognizant of balancing the emotional load for students whilst equipping them with knowledge and skills in this field. The course comprises three modules, each completed over one week. The module's content aligns with both the MDANZ Working Group learning objectives, and three of the four Australian Medical Council (AMC) domains for graduate outcomes; Science and Scholarship, Clinical Practice and Health and Society (42, 43). Throughout the program, we present a range of resources from different sectors, aimed at a variety of audiences for students to reflect upon how best to communicate about climate change and planetary health. Each module centers around carefully curated shared resources which lead to tasks for students to complete. These relate to real-world problem solving within Australian and international healthcare settings, with an emphasis on the Australian healthcare setting. Each task incorporates opportunities for student reflection. Once per week, learners and their academic facilitator engage in a small group tutorial, where they discuss their reflections and engage in case-based learning. The final week of the four-week course is set aside for preparing and delivering their final assessment presentations.

3.1 Module 1 relates to science and scholarship

This Module begins with the tenet that human health is fundamentally dependent on healthy ecosystems. As part of this module, students are tasked with watching an introductory presentation about planetary health and making a note of what

TABLE 1 Learning objects JMP sustainable healthcare course.

Week 1—module 1: science and scholarship
Outline the dependence of human health on global and local ecological systems which supply clean air, clean water and nutritious food and the Earth systems that provide a stable climate.
Discuss the contribution of human activity to global and local environmental changes such as climate change, and biodiversity loss and resource depletion in land and marine environments.
Describe the mechanisms by which human health is affected by environmental change, e.g. exposure to extreme weather, change in disease vectors, migration and decreasing food and water security.
Explain how the health impacts of environmental change are distributed unequally within and between populations and the disparity between those most responsible and those most affected by change.
Week 2—module 2: clinical practice
Prevent, diagnose and treat the adverse health effects attributed to climate change and environmental causes.
Propose ways to practice medicine sustainably by considering what models of care could reduce the environmental impact of best practice care and service delivery to patients.
Propose ways to practice medicine sustainably by considering the environmental impact of medications and other treatments in prescribing decisions.
Identify the vulnerabilities of health services and health facilities to climate change and extreme weather events and how these risks can be minimized and prepared for.
Explain the concept of 'health co-benefits' by considering how lifestyle choices can promote both patient well-being and a healthy environment.
Week 3 and 4—module 3: health and society, professionalism and leadership
Identify the role of health care professionals in advocating for policies and infrastructure that promote the availability, accessibility and uptake of healthy and environmentally sustainable behaviors.
Describe features of a health-promoting local environment, in community and healthcare settings, to include access to green spaces, clean air, and an active travel infrastructure.
Explain how trends in climate change may affect capacity to provide healthcare in the future.
Explain the contribution of the Sustainable Development Goals to addressing the socio-economic and environmental determinants of health.
Identify ways to improve the environmental sustainability of healthcare systems by reducing the carbon footprint through individual practice, health service management and the design of care systems.

Learning objectives derived from the MDANZ Working Group on climate change and health (4).

TABLE 2 Cohort Demographics of three year groups of Joint Medical Program Students who had completed the Sustainable Healthcare course by 2024.

Age Range (years)	18–24	25–30	31–39	40–50
	352 (60%)	174 (30%)	41 (7%)	15 (3%)
Gender	**Male**	**Female**	**Non-binary**	
	281 (48.3%)	299 (51.4%)	2 (0.3%)	
Total 582				

made the greatest impression on them. This is when students introduced themselves to each other within the group.

Students consider the effects of climate change in Australia as depicted in a video by the Bureau of Meteorology. The task is to consider what climate change impacts have been most apparent where each of the students are living or regard as home. Two articles are presented that utilized air quality data to determine the burden of disease, mortality and economic impact of the 2019–2020 bushfires in Australia (44, 45). This presents a chance for students to consider how environmental health data and modeling can be used to highlight impact contemporaneously, as well as how socioeconomic and health impacts of environmental change are unevenly distributed within and between populations.

In recognition that reading and thinking about climate change and other large scale environmental threats can be confronting, and sometimes distressing, students are referred to a resource "Coping with Climate Change Distress" developed by The Australian Psychological Society (39). Students are directed to think about how these techniques could be useful to themselves and others, and discuss which of the "recommended activities" in the resource resonate with them.

3.2 Module 2 relates to clinical practice

Within this Module students explore the need to adapt clinical practice to manage the health impacts of climate change, the ecological footprint of the healthcare system and the concept of "health co-benefits".

Students learn that health services and facilities are vulnerable to climate change and extreme weather events. They are directed to the World Health Organization "WHO Guidance for Climate Resilient and Environmentally Sustainable Health Care Facilities" to consider how the outlined consequences of climate change for health care facilities could apply to their region or a community of practice (46). The task is to bring to the tutorial an idea for a way of safeguarding the health care facility and/or its staff from this consequence of climate change and whom they could approach to have this implemented.

The Module examines how healthcare itself has a large ecological footprint. Students are directed to read an article that argues that health professionals have a role in advocating for reducing the environmental footprint of healthcare (47). In their assigned task, students think of an example of how they became more aware of their personal environmental impact and how this led to behavioral change. Students watch a presentation by the Local Health District's Executive Director of Infrastructure and Planning on leading and managing change in healthcare, such as new models of care to reduce environmental impact and achieve carbon neutrality whist maintaining best practice care for patients.

Additionally, the idea of sustainable medical clinical decision-making is introduced. Sustainability in medication prescribing is now mainstream in the UK's NHS (48), and explained in an article from the UK National Institute for Health and Care Excellence (49, 50). Students reflect on how they can apply these principles in patient consultations about respiratory inhalers, considering factors of patient preference, compliance and medication safety. The final component of this module introduces students to "health

co-benefits", highlighting that lifestyle choices can promote both patient well-being and a healthy environment. Students interact with television media from Australia's national broadcaster that engages viewers in understanding the carbon footprint of different foods. Students also contemplate the best way for patients to receive information about the environmental impact of medicines, diet and lifestyle advice.

3.3 Module 3 relates to advocacy

In Module 3, students consider opportunities for doctors and other health professionals to advocate for improved health of patients and the environment. Examples given include:

- Patient education about healthy lifestyle choices (diet, exercise, transport options) that have environmental co-benefits,
- Writing and releasing reports, contributing to public and academic forums,
- Position statements from professional colleges,
- Submissions to government committees of enquiry and lobbying members of parliament, and
- Media comment, interviews and advertisements.

Students read the report produced by Doctors for the Environment, Australia entitled "Net zero carbon emissions: responsibilities, pathways and opportunities for Australia's healthcare sector" and are tasked with discussing how effectively this report conveys its message and ways that it could be improved (51).

Students watch two interviews with one student and one clinician leader in the field of environmental advocacy and sustainable healthcare practice, and a TED talk by a representative of Doctors for the Environment. The task is for students to share perspectives on leadership qualities that they observe in watching these advocates. Students engage with a multi-media comedic article and reflect on how humor has a place in communication about planetary health issues (52).

Lastly, the Module highlights how planetary health relates to the United Nations' Sustainable Development Goals (SDGs). Multiple nations, including Australia, have signed up to the SDGs as a way of addressing socio-economic and environmental determinants of health, and these are pertinent to planetary health on an international scale. 'Health equity' is considered using resources of the World Health Organization and a presentation by Professor Michael Marmot on the socioeconomic determinants of health inequity (53). The task is to reflect on one of these SDGs and consider how health professional advocacy and action could enable progress toward this SDG in a particular community. This activity brings together a range of sustainability challenges, allowing students to consider a multidisciplinary lens for problem solving and to explore an interest area in more depth.

3.4 Tutorial case-based discussions

Throughout the course, small groups of 8–12 students meet weekly with a tutor for 90-minutes to review the learning from each module. The assigned reflective tasks form the basis of student led discussions, providing structure to the tutorials. Each week we give students the opportunity to write their name next to the two or three tasks for which they would like to lead the discussion and contribute what they have learned. This provides a reliable way of starting the group discussion and avoids what can otherwise be awkward pauses or students feeling put on the spot.

In addition, for each module the group navigates through a clinical case that is related to planetary health. Each case discussion includes aspects of altered illness patterns from climate change, as well as key tenets of clinical practice, ethics and the social determinants of healthcare.

The case study for Module 1 is an older woman who presents with a bushfire related exacerbation of asthma. As well as the clinical diagnosis and management of her condition, students consider issues including shared decision-making about the patient returning to her home, the risks that this may pose to her health, and longer-term worries about the prospect of fires becoming more frequent with climate change.

The case study for Module 2 is an older man who has a syncopal episode in his backyard during a heatwave. Students need to consider how to assess syncope, how to classify heat related illnesses, and both the acute and longer-term management priorities.

In Module 3 students discuss a young student who presents with a history of fever, rash and joint pains. Her travel history requires consideration of zoonoses including Ross River virus and dengue fever. Students discuss how environmental factors influence vector population breeding habitats and patterns, and the subsequent impact on disease incidence and geographical spread of communicable disease outbreaks. They explore the role of the public health units in prevention and response to such changes.

3.5 Assessment

In the assessment for this course students are required to submit a pre-recorded ten-minute presentation in week four of the course. All presentations are viewed in a seminar, with questions and student-led discussion following each presentation. Students need to choose three learning objectives to address in their presentation - one of the learning objectives from Module 1, one from Module 2, and one from Module 3. Since these are quite general, students are able to focus their presentation on a particular topic that is of most interest to them.

4 Experience of course delivery

This program has now been delivered to over 700 medical students since 2021. As this was a new program with delivery being online and utilizing zoom tutorials due to the COVID-19 pandemic, we were keen to understand how students engaged with the material and whether they could achieve the learning outcomes in a remote format. Following overall positive feedback, we continued to deliver this material online and this provided students with more choice of how and where they spend this month-long course.

The modules gave students the opportunity to explore the diversity of resources in as much or little depth as they liked. Being able to choose their own assignment topic and research in depth gave them the freedom to explore what was of interest to them, and creating a video was an engaging way to learn. For example, students' presentations have addressed topics as varied as anesthetic gases, microplastics, air pollution and active transport (Table 3). Some students drew on their own experiences living in a particular location, and personal experiences of climate impacts such as bushfires, floods and droughts. We received early feedback that students needed more direction about how much to cover given the range of areas was broad. We responded by ensuring that students were comfortable with the expectations after each tutorial and clear about the idea being to break complex information down into teachable moments for the other group members.

The reflective tasks, and subsequent discussions, were observed to have provided an opportunity for students to connect over common experiences, challenges and goals. The case-based learning applied the concepts of planetary health into a clinically relevant context. Students had many opportunities to link the cases to recent climate events, and relate them to their personal experiences of local bushfires, major flooding events and outbreaks of zoonoses such as Japanese encephalitis in previously unreported regions.

Each year, students have been asked to complete an anonymous evaluation about the sustainable healthcare course. Since its commencement in 2021, 51.1%, 39.7%, and 8.3% of the 360 respondents have rated the quality of the learning experience as excellent, good and satisfactory, respectively (RR = 53.3%). We have regularly incorporated feedback from students about changes that could improve the course. This included giving them further guidance about their assessment task, use of additional pre-tutorial resources, and discussion of optional activities that students could be involved with including the Australian Medical Students' Association (AMSA) Code Green initiative and attending a local "green" operating theater that featured environmentally sustainable innovations. A number of students have taken advantage of this opportunity. Two publications spotlight an example of how our course inspired further scholarship and student advocacy in the area of environmental sustainability in anesthetic practice (54, 55).

TABLE 3 Examples of assessment topics.

Topic area	Specific examples
Climate event or environmental hazard related to location	Sea level rise in Pacific Islands, Bangladesh and Japan, Water security for remote Indigenous communities in Australia, tuberculosis in India, malaria in Papua New Guinea, dengue fever in Singapore, Flooding in Malaysia, bushfires in Australia, heat waves in Japan
Environmental issue	Micro-plastics, pharmaceutical manufacture and waste, funerary practices, sanitation in healthcare, green spaces in hospitals
Clinical specialty	Environmental footprint of radiology, renal health with emphasis on dialysis, telehealth, surgical waste, anesthetic gases, public health initiatives

5 Discussion

Medical school curricula need to feature the changing environmental determinants of health and how students and doctors can be agents of positive change. However, the principle of "first do no harm" applies to the learning environment as it does to healthcare. How do we care for our students as they learn about planetary health, when increased awareness of climate change and other ecosystem changes can lead to distress, poorer mental health and burnout especially amongst those who may already be involved in advocacy?

We have applied several principles from motivational psychology in how we have delivered our sustainable health course, but more can be done. Educators need to be mindful of the impacts of planetary health content and assist learners in coming to terms with the enormity of the challenge and showing a path toward progress. Acceptance and commitment therapy or training, offers the practice of avoiding being hooked by unhelpful thoughts and ruminations that can lead to despair and instead identifying productive ways of thinking about the opportunities for moving in desired directions. Committed action is best planned by first being in touch with one's values. Our students are invited to consider their values in thinking about how health professional advocacy could achieve progress toward a sustainable developmental goal in a particular group in one exercise. However, this principle could be further applied by incorporating subsequent projects or teamwork exercises.

Self -determination theory explains that people are more likely to maintain intrinsic motivation and enjoyment in learning if their environment promotes autonomy, competence and relatedness. In our course we have implemented a number of strategies to enhance the learner's autonomy. Students chose which discussion points to lead during the tutorials, and the direction in which they take these. Students also have autonomy over the areas of interest to research and present to the group. The self-paced modular content and tutorials on zoom also provide flexibility and convenience for students. There are however limitations on autonomy in that the course and assessment are compulsory. This is overcome by some programs in having environmental sustainability as an elective choice, however this limits the reach of this important area of curriculum development.

In terms of relatedness, students in our example learn in small groups with a dedicated tutor, and have the opportunity to consider each other's perspectives as they reflect on their own learning and personal experiences. The reflective task in module one which asks students to describe what climate change impacts they have observed where they live or within the location they call home, fosters connection within the group by recognition of common experiences and concerns. A sense of relating to their community of practice is fostered by incorporating presentations from medical leaders who display openness in sharing their own challenges, hopes and fears. Likewise, the host in the featured mainstream media production on the carbon footprint of foods, shows vulnerability by expressing his own concerns, knowledge gaps and personal mistakes (56). Finally, the assessment task is a time for students to learn from each other and provides the opportunity for shared learning and encouragement. Further

possibilities to strengthen a sense of relatedness could include increasing time allocated within the course for group activities and sustainability projects with their wider community of practice.

Students may develop a sense of competence by problem-solving clinical approaches to a variety of patient presentations that relate to climate change and environmental health impacts. The design of the assignment allows students to acquire depth of knowledge in their particular areas of interest, which they utilize to educate and facilitate discussion with their peers. A number of the reflective tasks also provide students with an opportunity to practice a new skill and receive group feedback. In module 2, for example, students reflect on the coaching model of balancing support and challenge, and describe how they could utilize this to make a change in their own lives. Students bring this to the tutorial to discuss and receive feedback. While these tasks support the development of competence, students are not formally assessed on levels of competence during the course. Ways of doing so could include embedding hands-on experiences within the course for students to practice and be assessed on their clinical or advocacy skills.

Our course draws on concepts of adaptive coping. Within the first week of our course we check in with students during the tutorial about their reactions to the content and provide them with resources that promote emotion focused coping (39). Students are invited to share particular adaptive coping strategies that resonate with them. Part of our strategy is to provide positive examples of progress in environmental sustainability, and provide a sense of hope for a better future. A benefit of this is that students learn about skills that could help their own future patients to deal with climate change distress.

Educators in all disciplines need to consider how best to engage learners. Planetary health has the potential to overwhelm learners with its scope, and to lead to distress about the concerning trajectory of climate change and environmental degradation. At the same time, there is the opportunity to inspire medical students to embrace the challenge of protecting the health of patients and communities from current impacts of extreme weather events and ecosystem damage, and to develop adaptive capacity for a changing world. Being mindful of relevant and helpful psychological theories and interventions can help to sustain learners and to assist in positive change and solutions that promote environmental sustainability and safeguard the future.

6 Acknowledgment of context

Introducing new curricula with considerable time allocation is typically challenging due to the existing content-dense medical curricula. In this case, the cancellation of an elective community placement in which many students traveled overseas, due to the COVID-19 pandemic provided an opportunity to introduce this content. Students now have the opportunity to learn about planetary health embedded into their medical education, while the overseas elective opportunities were shifted to later in the degree.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

NJ: Writing – original draft, Writing – review & editing. GH: Writing – original draft, Writing – review & editing. MG: Writing – original draft, Writing – review & editing. GB: Writing – review & editing. JB: Writing – review & editing.

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Conflict of interest

At the time of writing, GB was a voluntary Board Director for the non-profit organisation Doctors for the Environment Australia.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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