PLOS Climate

RESEARCH ARTICLE

Improving health professionals' capacity to respond to the climate crisis: Outcomes of the Caribbean climate and health responder course

Cecilia Sorensen[1,2*], **Danielly de Pavia Magalhaes**[1], **Haley Campbell**[1], **Nicola Hamacher**[1], **Jessica Patel**[2], **Paula Henry**[3], **Christopher Oura**[4], **James Hospedales**[3]

1 Global Consortium on Climate and Health Education, Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, New York, United States of America, **2** Department of Emergency Medicine, Columbia University Irving Medical Center, Columbia University, New York, New York, United States of America, **3** EarthMedic and EarthNurse for Planetary Health, Port of Spain, Trinidad and Tobago, **4** Department of Basic Veterinary Sciences, University of the West Indies, Saint Augustine, Trinidad and Tobago

* CJS2282@cumc.columbia.edu

Citation: Sorensen C, Magalhães D de P, Campbell H, Hamacher N, Patel J, Henry P, et al. (2025) Improving health professionals' capacity to respond to the climate crisis: Outcomes of the Caribbean climate and health responder course. PLOS Clim 4(6): e0000566. https://doi.org/10.1371/journal.pclm.0000566

Editor: Shlomit Paz, University of Haifa, ISRAEL

Received: October 29, 2024

Accepted: May 14, 2025

Published: June 9, 2025

Data availability statement: We fully accept all clauses outlined in the Data Availability policy. All data underlying the findings of this manuscript will be made fully available and has been attached as supplemental information. We

Abstract

Despite broad recognition of climate change as a critical health threat, a significant global knowledge gap persists among health professionals. To address this issue, the second iteration of the Caribbean Climate and Health Responder Course: Education For Action was launched in partnership with EarthMedic and EarthNurse (EM&EN), the University of the West Indies, and the Global Consortium on Climate and Health Education (GCCHE). This course aimed to enhance participants' knowledge, confidence, preparedness, and sense of professional responsibility regarding the health impacts of climate change in the Caribbean, using science-based evidence to improve communication and action among health professionals. The course was delivered online via Zoom, and featured 10 sessions that included lectures, case studies, and discussions, with simultaneous English and Spanish interpretation to reach a broader audience. Participants were evaluated through pre- and post-course surveys and a final exam, measuring changes in awareness, communication skills, preparedness, and sense of professional responsibility. Results from a self-reported survey of 505 participants showed significant improvements. The highest rating (10) was selected more frequently, indicating increased confidence in key areas: awareness of climate change impacts (12.3%), communication skills (18–21%), preparedness (14.8%), and responsibility in climate mitigation (12.7%). The final exam results confirmed a high pass rate, validating the course's effectiveness. The findings suggest the course effectively bridged the knowledge gap and recommended ongoing updates to training content, a greater focus on communication skills, and localized preparedness training to address regional challenges.

have no restrictions regarding their publication, in accordance with PLOS Data Policy.

Funding: The author(s) received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

1. Introduction

Climate change is a health issue impacting morbidity, mortality, and healthcare delivery globally. [1] The health impacts of climate change are particularly severe throughout the Caribbean as the region experiences amplified climate threats due to its geography, including extreme weather events and hurricanes, heat waves, degraded air quality from Saharan dust, floods, and droughts [2–4]. These impacts are expected to intensify throughout this century [5].

As global temperatures increase, the Caribbean is experiencing more intense and prolonged heat waves, as evidenced by 2023 being the region's warmest year on record [4]. Extreme heat events can lead to heat exhaustion, heatstroke [6], and worsen pre-existing health conditions, particularly cardiovascular [7] and respiratory diseases [8], resulting in a rise in all-cause mortality. Additionally, climate change is altering mosquito habitats and behaviors, contributing to the spread of diseases such as dengue, chikungunya, and Zika in the region. Recently, the Caribbean has faced an unprecedented crisis with co-occurring epidemics of these febrile illnesses [9]. In 2023, the Caribbean reported 95,024 cases of dengue, a significant increase from 13,991 in 2003 [10].

Furthermore, while the Caribbean has long been accustomed to hurricanes, the region is now confronting increasingly powerful and destructive storms as a direct consequence of climate change [4]. Hurricanes cause widespread devastation, leading to physical injuries, displacement, and long-term health issues, including mental health challenges and infectious disease outbreaks [11]. Climate impacts on health systems pose demand challenges as surges in patient load can overwhelm facilities; service delivery challenges if communication and transport links are disrupted or health facilities damaged; and a health determinants challenge, e.g., through impacting water and food security. Additionally, the region is at greater risk for waterborne diseases such as cholera, leptospirosis, and gastroenteritis due to increased flooding and changes in water quality during the hurricane season [12–14]. Vulnerable populations, such as older adults, children, and those with chronic illnesses, outdoor workers and others are at even greater risk [1], with excess mortality after disasters greatly exceeding the event's death toll, e.g., following Hurricane Maria in Puerto Rico in those with previous chronic illnesses [15]. Additionally, climate change exacerbates ongoing social and economic inequalities, as well as can deteriorate existing adaptive capacity, with the poorest populations suffering the most due to limited access to healthcare, clean water, and nutritious food [16,17].

While climate policies are often national, their impacts are first experienced locally [18]. Caribbean ministries of health have identified health professional training as a key priority in their Climate and Health Country Profiles to strengthen health systems [19–21]. Health professionals must be equipped to identify, communicate, and respond to climate-related health challenges, understand these issues, and engage in shaping institutional, local, and national policies to protect vulnerable populations.

Despite widespread recognition of climate change as a health threat by health professionals, a significant knowledge gap persists globally, particularly in low- and middle-income countries [22]. The IPCC emphasizes that proactive adaptation can

reduce health risks [23], and the 77th World Health Assembly's Climate Change and Health Resolution WHA A77/A/CONF./7 calls for capacity building among health professionals to achieve climate-resilient health systems [21] as does the Antigua and Barbuda Agenda for SIDS [24]. However, climate change education remains largely absent from health professional training, resulting in an unprepared workforce to address climate-related threats [25].

To address this gap, the second iteration of the Caribbean Climate and Health Responder Course: Education For Action was launched through a partnership between EarthMedic and EarthNurse (EM&EN), the University of the West Indies, and the Global Consortium on Climate and Health Education (GCCHE). This course focuses on the major health impacts of climate change in the Caribbean, providing science-based evidence to improve knowledge, skills, communication, and action among health professionals. This manuscript details the course structure, content, and delivery methods, and evaluates the effectiveness of a climate and health course tailored for professionals in the Caribbean region. Next, we present an analysis of longitudinal changes in participants' knowledge, confidence, preparedness, and sense of professional responsibility regarding climate and health, offering insights for refining and scaling similar educational interventions.

2. Methods

2.1 Educational model and course structure

This course was designed for health professionals across varying levels of experience and different specialty and subspecialty backgrounds. The curricular foundation of this educational initiative was the GCCHE core competencies for health professionals, a set of highly-vetted global educational standards which cover climate and health analytic skills and knowledge, communication and collaboration, policy, and public health and clinical practice competencies [26], which were systematically translated into progressive learning objectives using Bloom's taxonomy. This hierarchical framework guided our curriculum design by classifying educational objectives from basic knowledge acquisition to complex analytical skills, while ensuring the objectives were applicable to all health professional backgrounds. The session topics and learning objectives were reviewed by health professionals at EarthMedic and EarthNurse (a Caribbean-based civil society organization) and the University of the West Indies, to ensure they accurately reflect Caribbean climate challenges, socioeconomic determinants of health, cultural knowledge, and local needs.

The pedagogical approach centered on problem-based learning through regional case studies, which research has shown effectively bridges theoretical knowledge and practical application in healthcare education [26]. Each session's case study was carefully selected to demonstrate real-world applications of the session's content, allowing participants to engage with authentic regional challenges while practicing critical thinking skills. This approach aligns with adult learning principles that emphasize relevance and practical application [27].

Synchronous online discussions were integrated as a deliberate educational strategy based on social constructivist learning theory [28], which emphasizes knowledge construction through social interaction. Verstegen et al. demonstrated that well-facilitated online synchronous discussions can achieve comparable learning outcomes to face-to-face interactions, particularly when addressing complex interdisciplinary topics [29].

The course was delivered online twice a week via the Zoom webinar platform and consisted of 10 sessions, each lasting 90 minutes (see S1 Text for the course curriculum). These sessions focused on the major health impacts of climate change in the Caribbean region. Each session featured a 45-minute didactic lecture, followed by a 20-minute case study presentation and a synchronous online discussion segment during which participants could engage directly with the speakers. This case-based learning, which integrates theoretical knowledge with real-world scenarios, fosters critical thinking and problem-solving abilities by immersing participants in practical situations that reflect regional challenges they may face in climate and health projects, effectively bridging the gap between theory and practice. Synchronous online discussion is central to problem-based learning, promoting constructive reflection and analysis [26]. Research indicates that well-prepared synchronous communication through web-conferencing tools can be as effective as face-to-face group discussions [30].

The lectures and case studies were presented mainly by Caribbean experts, offering a comprehensive and regionally relevant overview of the specific challenges experienced in the Caribbean. While the primary language of instruction was English, simultaneous, Spanish interpretation was provided in order to accommodate a broader audience. The course was offered free of charge.

2.2 Registration and longitudinal survey

Participants were registered during recruitment and outreach efforts conducted seven weeks prior to the course launch through the partners' networks including GCCHE mailing lists, EM&EN social media channels, marketing and communication channels at the UWI, National and Regional medical and nursing professional associations, and the Pan American/World Health Organization. Engagement was further supported by a WhatsApp group that provided reminders, shared materials, and facilitated direct interaction with course coordinators once participants were registered.

A pre-course survey was included in the registration process, which featured demographic questions. To evaluate the course's effectiveness, we conducted pre- and post-course surveys enabling participants to self-assess their competencies related to specific objectives, such as participants' climate awareness, confidence, and behaviors related to their ability to communicate the health impacts of climate change, their preparedness to act on climate and health plans, and their sense of responsibility in contributing to climate adaptation and mitigation efforts within their communities (See S2 Text for survey questionnaire).

The longitudinal survey was modified from prior GCCHE course surveys by GCCHE experts with the intent to align with the course's learning objectives and assess participants' knowledge, skills, and attitudes related to climate change and health.

The survey responses were measured using a Likert scale, with options ranging from 1 to 10. For a question measuring *impact*, a response of 1 indicated "Not relevant – Climate change does not impact my professional practice," while a 10 indicated "To a large extent – Climate change impacts all facets of my professional practice." For questions assessing *confidence*, a response of 1 indicated "Not confident," while a response of 10 indicated "Very confident." For questions evaluating preparedness, a response of 1 indicated "I feel unprepared," while a 10 indicated "I feel very prepared." For questions assessing participants' sense of professional *responsibility*, a response of 1 indicated "I feel no responsibility," while a 10 indicated "I feel a very high sense of responsibility."

Following the course, participants completed a final exam to assess mastery of the learning outcomes associated with each session. The final exam consisted of 24 multiple-choice and true/false questions, with each question worth 1 point, resulting in a maximum possible score of 24. Following the final exam, participants completed a post-course longitudinal survey, which repeated the pre-course questions to assess any changes in their knowledge, communication confidence, preparedness, and sense of professional responsibility related to climate change.

2.3 Course participation and certification

The day after the course concluded, all participants received an invitation via email and WhatsApp with a link to complete the final exam on Qualtrics. Participants were required to complete the final exam in one sitting within 48 hours of the final course session. There was no time limit to finish the exam once it started. The final exam was offered in both English and Spanis. Participants who attended at least 70% of the Zoom sessions and scored 70% or higher on the final exam were eligible for a Certificate of Participation. Additionally, one Continuing Medical Education (CME) credit was awarded for each session to participants from the Caribbean, with the requirements being full session attendance and completion of a post-session evaluation.

2.4 Analysis

All data from registration, course participation and both pre- and post-surveys was analyzed using STATA software. Additional analysis of statistical significance using Wilcoxon signed rank tests and two-sample proportion tests was completed

using R software (version 4.4.1). The analysis included only participants who completed both the pre and post-course longitudinal survey.

Data was first analyzed and checked for duplicate entries by participants. Out of the duplicate entries, the participants' most recent submission was kept for data analysis.

For each longitudinal survey question, the change in the number of participants and the percent change from the pre-survey to the post-survey were calculated for each answer choice. This change was determined by subtracting the number of participants' responses in the post-survey from those in the pre-survey. The resulting difference represents the shift in participant responses over time and represents the impact of the course on participant responses.

Furthermore, a reliability analysis was performed on these longitudinal survey questions.In Stata, reliability analysis was conducted using Cronbach's alpha to assess the internal consistency of the survey scale. The command "alpha varlist" was used to determine the overall reliability coefficient. It was found that dropping longitudinal question 1, "To what extent do the impacts of climate change on health affect the work you do in your professional practice?", would yield a higher alpha. Question 1 was excluded because it measured perceived climate change impact rather than skill acquisition, making it misaligned with the other survey items.

After assessing item-total correlations and potential improvements to reliability, a new scale was created using longitudinal questions 2–7 to calculate a mean pre and post course survey score was then calculated to evaluate changes in participant responses over time.

P-values for comparison values from initial survey to post-survey were calculated using a two-sample proportion test. Statistical significance on a question by question basis was performed using a Wilcoxon signed rank test.

Finally, the end of course exam scores were assessed by examining the median scores for all participants as well as the 25th and 75th percentiles to assess the distribution of participant performance.

3. Results

3.1 Demographics and participation

The course attracted 2,075 registrants, representing over 115 countries (See S1 Table), each of whom completed the pre-course survey. Among these registrants, approximately 27% (n = 560) identified as students, and 28% (n = 581) had received prior training in climate and health.

The post-course survey was completed by 548 participants. Only participants who completed both the pre- and post-course survey (n = 505), were included in the longitudinal analysis. Participant data included in the longitudinal survey represented 65 countries. About 23% (n = 116) of these participants (23%) were from Mexico, and 52% (n = 261) identified as being from Caribbean countries (Table 1).

The majority of participants came from the government or intergovernmental sector (45%, n = 228), followed by those in academia or research (21%, n = 105), the private sector (9%, n = 45), non-governmental organizations (8%, n = 41), and other sectors (17%, n = 46) (Table 2). Many participants worked in the fields of healthcare (48%, n = 240 - nurse, medicine/doctor, mental health professional, emergency responder, pharmacist, occupational health, physical/occupational/speech therapy, advanced practice provider, clinical social worker) or public health (21.2%, n = 107 - public health, public health policy and public health informatics) (Table 3). English was the preferred language for 67% (n = 338)of participants, while 33% (n = 167) preferred Spanish.

3.2 Longitudinal survey

The results of the longitudinal survey are presented in Figs 1–4 and S2 Table, evaluating the course's impact on participants' skills and perceptions across four key areas: awareness, communication, preparedness, and professional responsibility related to climate change and health. The survey results are segmented according to these course objectives, providing insights into how participants' views and capabilities evolved over the duration of the course.

Table 1. Caribbean countries of residence for course registrants and final survey participants.

Country/Region Name	Registered (n = 2,075)	Survey Participants (n = 505)
Trinidad and Tobago	258 (12.4%)	77 (15.2%)
Jamaica	274 (13.2%)	60 (11.9%)
Haiti	101 (4.9%)	32 (6.3%)
Barbados	61 (2.9%)	14 (2.8%)
Bahamas	38 (1.8%)	13 (2.6%)
Saint Lucia	48 (2.3%)	10 (2.0%)
Grenada	39 (1.9%)	9 (1.8%)
Turks and Caicos Islands	20 (1.0%)	9 (1.8%)
Antigua and Barbuda	25 (1.2%)	8 (1.6%)
Saint Vincent and the Grenadines	23 (1.1%)	8 (1.6%)
Belize	26 (1.3%)	4 (0.8%)
Dominica	21 (1.0%)	4 (0.8%)
Costa Rica	12 (0.6%)	3 (0.6%)
Puerto Rico	19 (0.9%)	3 (0.6%)
Saint Kitts and Nevis	8 (0.4%)	3 (0.6%)
Curaçao	8 (0.4%)	1 (0.2%)
Dominican Republic	7 (0.3%)	1 (0.2%)
Honduras	3 (0.1%)	1 (0.2%)
Virgin Islands (British)	8 (0.4%)	1 (0.2%)
Anguilla	1 (0.05%)	0
Cayman Islands	2 (0.1%)	0
Guadeloupe	1 (0.05%)	0
Montserrat	2 (0.1%)	0
Sint-Maarten (Dutch)	2 (0.1%)	0
Virgin Islands (U.S.)	4 (0.2%)	0
Total	1011 (48.7%)	261 (51.7%)

**This is a modified list of countries only showing the Caribbean countries where our participants were from. Registrants and participants were from diverse nations including but not limited to areas in North America, Central America, South America, Africa, Asia and Europe.*

***See S1 Table for a full list of countries of registrants and final survey participants.*

https://doi.org/10.1371/journal.pclm.0000566.t001

Table 2. Work sector for participants and final survey participants.

Place of Work	Registered (n = 2,075)	Survey Participants (n = 505)
Government/Inter-governmental	938 (45.2%)	228 (45.2%)
Academic/Research Institution	448 (21.6%)	105 (20.8%)
Other	236 (11.4%)	86 (17.0%)
Private Sector	210 (10.1%)	45 (8.9%)
Non-governmental organization/Non-profit	243 (11.7%)	41 (8.1%)

https://doi.org/10.1371/journal.pclm.0000566.t002

3.2.1 Awareness. Compared to the beginning of the course, the number of participants reporting that climate change impacts all aspects of their professional practice to a large extent increased significantly (Fig 1, S2 Table). At the start, 30.6% (n = 154) of participants felt that climate change impacted all aspects of their professional practice to a large extent

Table 3. Reported occupations of course registrants and final survey participants.

Reported Occupation	Registered (n = 2,075)	Survey Participants (n = 505)
Public Health	462 (22.3%)	100 (19.8%)
Nurse	325 (15.7)	129 (25.5%)
Medicine/Doctor	406 (19.6)	82 (16.3%)
Environmental Health	206 (9.9%)	44 (8.7%)
Other	109 (5.3)	29 (5.7%)
Epidemiology	89 (4.3%)	26 (5.2%)
Educator	68 (3.3%)	9 (1.8%)
Mental Health Professional	38 (1.8%)	14 (2.8%)
Public Health Policy	35 (1.7%)	6 (1.2%)
Environmental Engineering	31 (1.5%)	5 (1.0%)
Natural/Physical Science	28 (1.4%)	8 (1.6%)
Veterinarian	27 (1.3%)	3 (0.6%)
Emergency Responder	26 (1.3%)	9 (1.8%)
Social Work	26 (1.3%)	5 (1.0%)
Engineering	24 (1.2%)	6 (1.2%)
Consultant	23 (1.1%)	4 (0.8%)
Laboratory Technician	21 (1.0%)	6 (1.2%)
Pharmacist	20 (1.0%)	1 (0.2%)
Health Administration	18 (0.9%)	4 (0.8%)
Occupational Health	15 (0.7%)	2 (0.4%)
Dentist	10 (0.5%)	2 (0.4%)
Economics/Finance	10 (0.5%)	1 (0.2%)
Physical/Occupational/Speech Therapy	9 (0.4%)	1 (0.2%)
Advanced Practice Provider	7 (0.3%)	1 (0.2%)
Communications/Marketing	7 (0.3%)	0 (0%)
Law	7 (0.3%)	2 (0.4%)
Public Policy	7 (0.3%)	0 (0%)
Biostatistics	5 (0.2%)	3 (0.6%)
Journalism/Media	5 (0.2%)	0 (0%)
Urban Planning/Architecture	4 (0.2%)	1 (0.2%)
Clinical Social Worker	3 (0.1%)	1 (0.2%)
Public Health Informatics	2 (0.1%)	1 (0.2%)
Information Technology	1 (0.1%)	0 (0%)
Philanthropy	1 (0.1%)	0 (0%)

https://doi.org/10.1371/journal.pclm.0000566.t003

(rating 10). By the end of the course, this percentage increased significantly by 12.3%, with 42.9% (n = 216) selecting the highest impact rating (p-value <0.001).

Conversely, the proportion of participants who felt that climate change did not impact their professional practice at all (rating 1) decreased from 8.2% (n = 41) at the beginning to just 2.2% (n = 11) by the end of the course, reflecting a statistically significant 6% decline (p-value <0.001).

Overall longitudinal change for this question was statistically significant at the 0.001 level.

3.2.2 Communication skills. Compared to the beginning of the course, study participants reported increased confidence communicating with members of their community as well as their patients (if applicable) (Fig 2, S2 Table). Initially, 17.6% (n = 89) of participants rated their confidence at the highest level (rating 10) in communicating with their

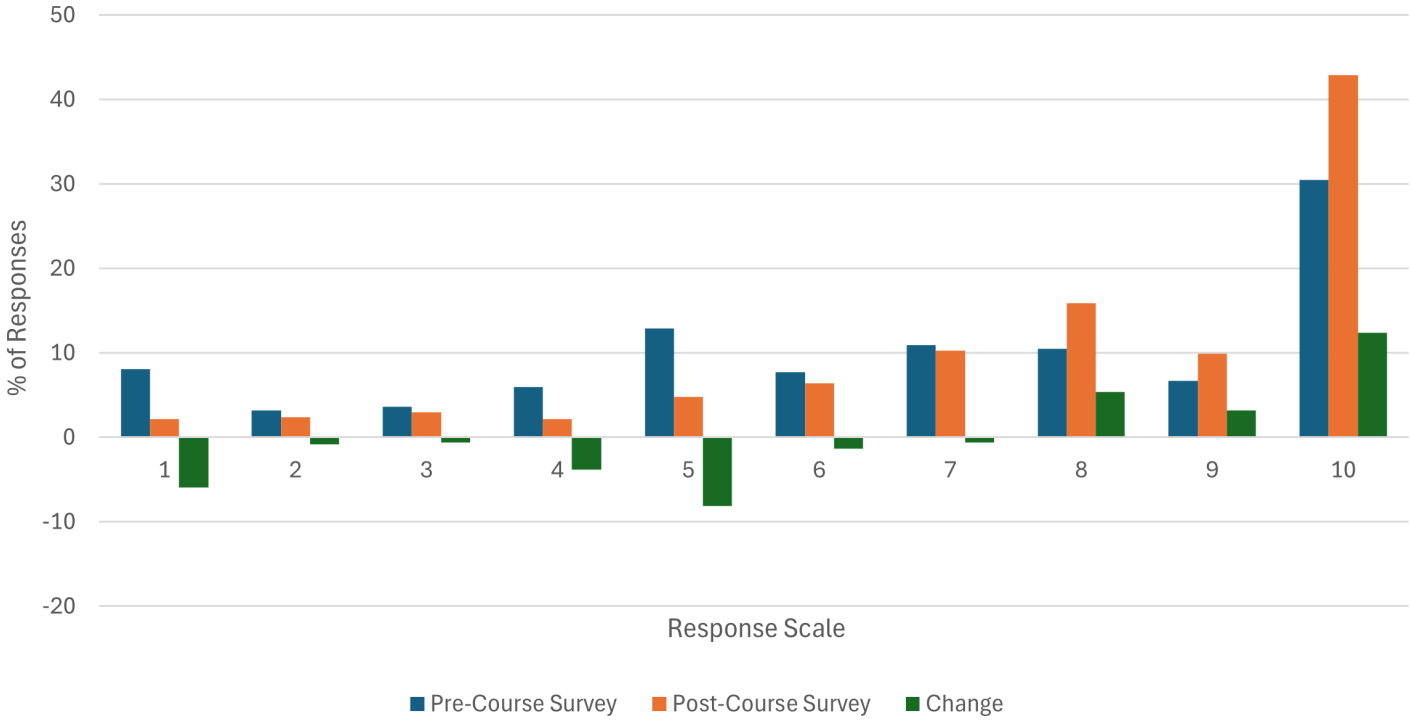

Fig 1. Percentage distribution of pre- and post-course responses and the percentage change regarding awareness. *Q1 asked "To what extent do the impacts of climate change on health affect the work you do in your professional practice?".* Responses were rated on a Likert scale from 1 ("Not relevant - Climate change does not impact my professional practice") to 10 ("To a large extent - Climate change impacts all facets of my professional practice").

https://doi.org/10.1371/journal.pclm.0000566.g001

communities on the health impacts of climate change. This number increased by 18.0%, with 35.6% (n = 180) reporting maximum confidence by the course's end, a statistically significant improvement (p-value <0.001).

The number of participants who felt little to no confidence (ratings 1 and 2) dropped significantly (p-value < 0.001, p-value < 0.05 respectively). For example, those who rated their confidence as 1 decreased from 9.9% (n = 50) to just 0.8% (n = 4), reflecting a 9.1% decline.

Regarding communication with patients, at the start, 17.6% (n = 73) of clinical participants rated their confidence at the highest level (rating 10), which rose by 21%, with 38.6% (n = 160) selecting this rating by the end of the course (p-value < 0.001). Confidence ratings of 8 and 9 also saw statistically significant increases of 9.4% (n = 39) and 7.5% (n = 31), respectively. Meanwhile, the percentage of participants who rated their confidence as very low (rating 1) dropped from 10.4% (n = 43) to just 1% (n = 4), reflecting a 9.4% decline. Those who rated their confidence at 5 also saw a significant decrease of 11.6% (n = 48).

Overall longitudinal change for both communication centered questions was statistically significant at the 0.001 level.

3.2.3 Preparedness. Participants reported significant improvements in their confidence of being prepared to take action or respond to help their communities and health systems to adapt to climate change by the end of the course (Fig 3, S2 Table). Compared to the beginning of the course, participants who rated their preparedness as a 10, or "very prepared," increased by 14.8% (n = 75) (p-value <0.001). By course completion, 25.7% (n = 130) of participants felt "very prepared," and a significant 78.8% (n = 398) rated their preparedness as 7 or higher (p-value <0.001). Notably, the number of participants who felt minimally prepared (ratings 1–4) dropped sharply, with a decrease of 28.1% (n = 142).

Similarly, when asked the degree to which individuals feel prepared to help health systems decarbonize and become more resilient to the impacts of climate change, participants also showed marked improvements. The percentage of

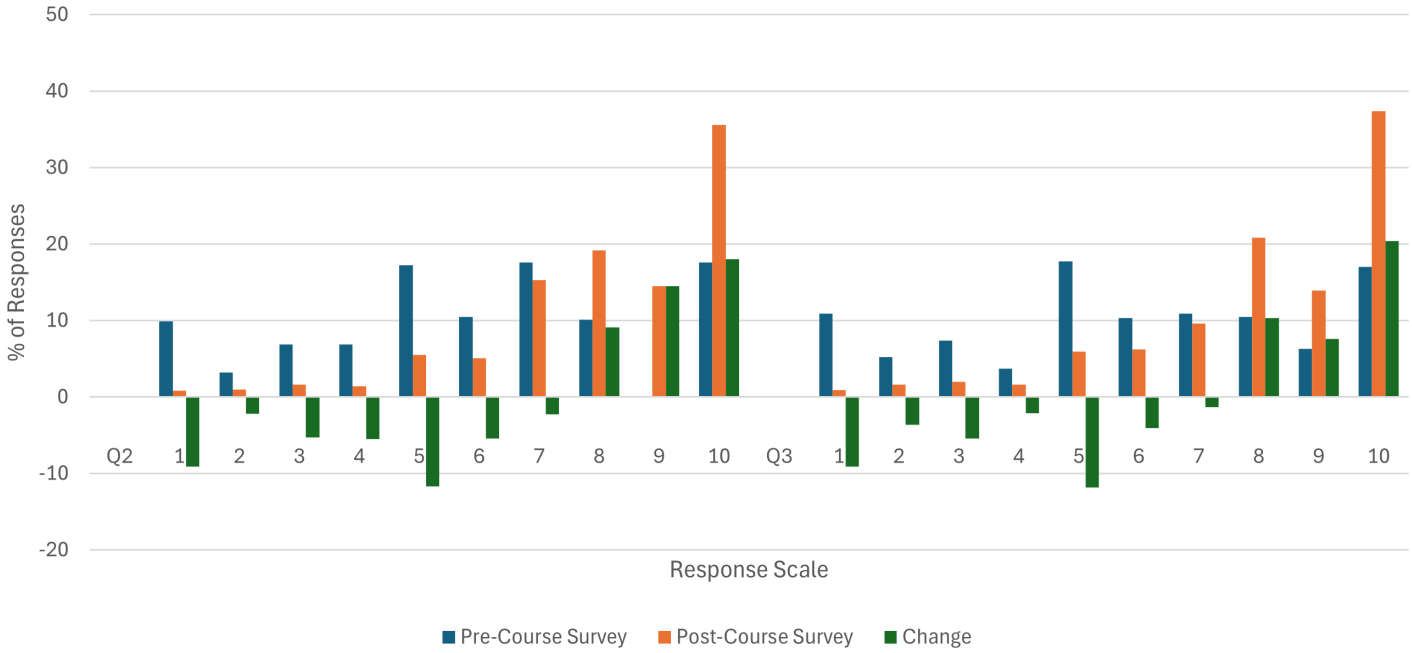

Fig 2. Percentage distribution of pre- and post-course responses and the percentage change regarding communication. Q2 asked "How confident do you feel communicating with members of your community about the health impacts of climate change?" and Q3 asked "if applicable, How confident do you feel communicating with patients about the health impacts of climate change?". Responses were rated on a Likert scale from 1 ("not confident") to 10 ("very confident").

https://doi.org/10.1371/journal.pclm.0000566.g002

participants who felt "very prepared" (rating 10) increased by 11.3% (n = 57), with 22.8% (n = 115) reaching this level by the end of the course. Additionally, 12.1% (n = 61) of participants rated their preparedness as 9, reflecting an 8.5% increase. Conversely, those who felt minimally prepared (ratings 1–4) saw a significant decline, with a decrease of 26.8% (n = 136).

Overall longitudinal change for both questions related to preparedness was statistically significant at the 0.001 level.

3.2.4 Professional responsibility. At the start of the course, 28.5% (n = 144) of participants rated their sense of professional responsibility to help their community adapt to health threats from climate change as a 10, or "high sense." (Fig 4, S2 Table) By the end of the course, this percentage decreased by 16.8% to 11.7% (n = 59). However, 83.5% (n = 422) of participants rated their sense of responsibility as greater than 5, with the most notable increase being in those rating it as 8, which rose by 26.1% to 38.8% (n = 196). In terms of helping their health system decarbonize and become more resilient, 26.5% (n = 134) initially rated their responsibility as a 10, and this increased by 12.7% to 39.2% (n = 198) by the end of the course.

While overall longitudinal change in response to participants' sense of professional responsibility to help their community adapt was not statistically significant; the degree to which participants sense of professionally responsible to help decarbonize and improve health system resilience increased significantly at the 0.001 level.

3.3 Longitudinal survey reliability analysis

A reliability analysis was conducted to assess the internal consistency of the longitudinal survey. It was found that removing Question 1, "To what extent do the impacts of climate change on health affect the work you do in your professional practice?", would increase the Cronbach's alpha from 0.8948 to 0.9104. This question differed in focus from the remaining six questions, which concentrated on participants' confidence in communicating about health impacts, their capability to address climate change, and their perceived professional responsibility.

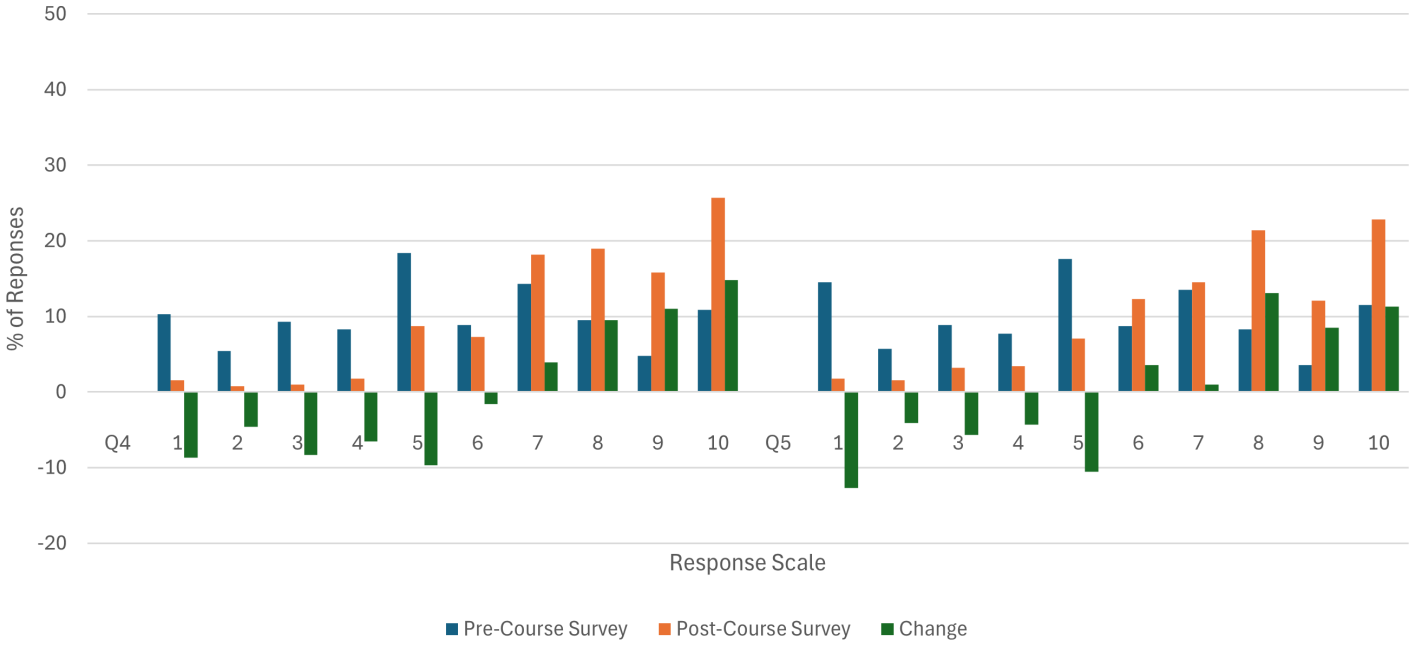

Fig 3. Percentage distribution of pre- and post-course responses and the percentage change regarding preparedness. *Q4 asked, "To what degree do you feel prepared to: Help your community adapt to the health threats of climate change?" and Q5 asked, "To what degree do you feel prepared to: Help your health system decarbonize and become more resilient to the impacts of climate change?".* Responses were rated on a Likert scale from 1 ("unprepared") to 10 ("very prepared").

https://doi.org/10.1371/journal.pclm.0000566.g003

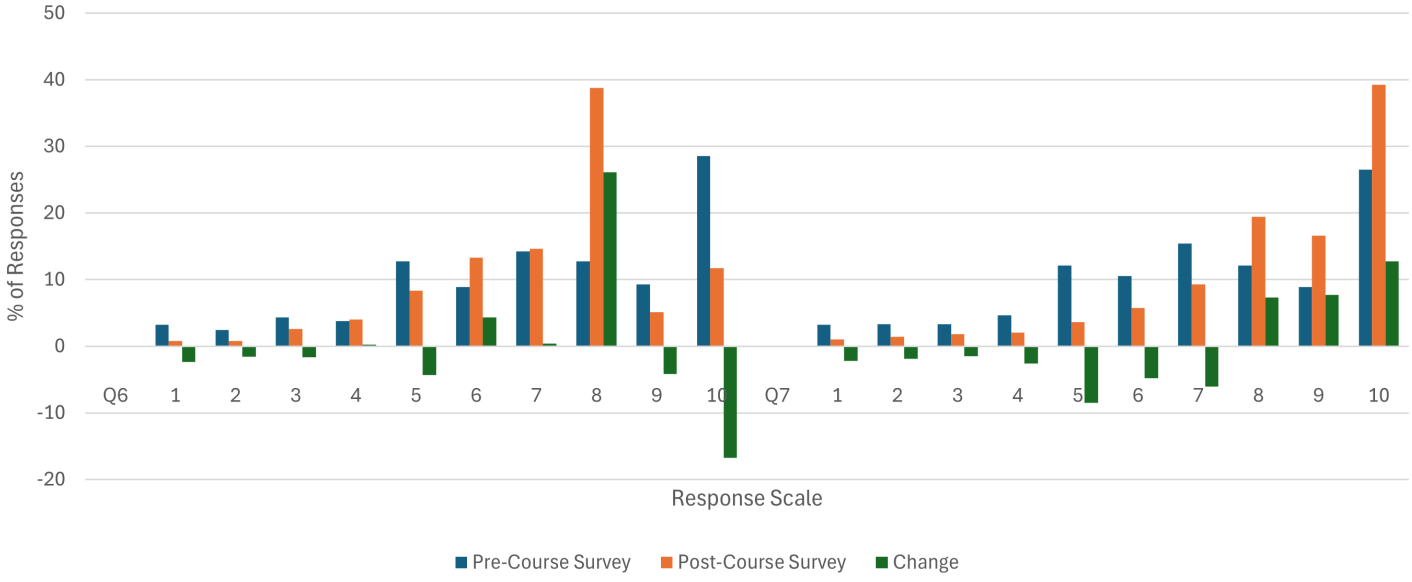

Fig 4. Percentage distribution of pre- and post-course responses and the percentage change regarding professional responsibility. Q6 asked, "To what extent do you feel a professional responsibility to help your community adapt to the health threats of climate change?", and Q7 asked "To what extent do you feel a professional responsibility to help your health system decarbonize and become more resilient to climate change impacts?." Responses were rated on a Likert scale from 1 ("no responsibility") to 10 ("very high responsibility").

https://doi.org/10.1371/journal.pclm.0000566.g004

After omitting Question 1, the revised reliability analysis yielded an alpha of 0.91, indicating excellent internal consistency. This high alpha value demonstrates that the remaining items are highly correlated and consistently measure respondents' attitudes and behaviors related to climate change. Additionally, the alpha for each individual item was lower than the overall alpha, confirming that none of the items were diminishing the scale's reliability.

A new scale was created using Questions 2–7. The theoretical range of this scale was from 6 to 60, with higher scores indicating more positive attitudes towards communicating about and responding to climate change impacts. The mean score at follow-up (47.05) was significantly higher than the baseline score (37.14), as shown by a paired t-test ($p < 0.001$). This suggests that the course had a meaningful impact on participants' understanding and attitudes towards climate change.

3.4 End of course exam

To pass the final exam, participants needed to score at least 70%, which equates to a minimum of 17 correct answers out of 24 questions. The median score was 19, the 25th percentile was 17, and the 75th percentile was 23. This indicates that 75% (n = 379) of participants scored at least 17, meeting the minimum passing requirement, while only 25% (n = 126) scored below this threshold and, therefore, did not pass the exam. The fact that the median is above the passing threshold of 17 demonstrates a generally successful outcome.

4. Discussion

Health professionals from all backgrounds are essential to prepare communities and health systems to respond to the climate crisis, yet many barriers prevent health professional engagement and meaningful action to mitigate the root causes of climate change and adapt their health practice to protect patients and communities, especially in vulnerable areas. In this course, participants from 65 countries across various health-related fields and professional settings reported improvement in awareness, communication skills, readiness, and sense of professional responsibility related to climate change.

While previous global [31] and Caribbean surveys [32] have highlighted health professionals' awareness of climate change impacts, our longitudinal survey revealed an increased recognition of how these impacts affect their personal professional practice after completing the course. This suggests that the course effectively improved participants' understanding of the direct relevance of climate change to their work, deepening their awareness and integrating climate change into their professional perspective, which is necessary to stimulate action.

Effective communication is crucial, given that health professionals are viewed as the most trusted voices within their communities [33]. According to a survey of Caribbean health professionals, 45% identified a lack of knowledge as the primary barrier to effective communication. Notably, 89% of these professionals had never received formal training or education on climate and health [32]. However, after participating in this course, attendees reported increased confidence in their ability to communicate about climate and health with their communities and patients, suggesting that this intervention may be a rapidly scalable tool to address pervasive climate and health knowledge gaps among health professionals in the Caribbean and beyond.

Participants demonstrated significant improvement in their reported preparedness to support community adaptation and assist the health system in decarbonizing and building resilience. However, further evaluation is needed to contextualize this improved capability within the specific challenges faced by health systems and communities and to assess what other supports are needed, e.g., skills training or more supportive environments. This finding is particularly important in light of previous research showing a lack of focus on public health preparedness and response in the Caribbean, despite the region's high vulnerability to extreme weather events exacerbated by climate change [34].

An interesting result emerged regarding participants' sense of professional responsibility. While the percentage of participants rating their responsibility to help their community adapt as "high" (10) decreased from 28.5% (n = 144) to 11.7% (n = 59), a significant majority (83.5%, n = 422) still rated their responsibility above 5. This decrease might reflect a shift in

perception rather than a decline in commitment. The Dunning-Kruger effect may explain this, where initial overconfidence diminishes as individuals gain a deeper understanding of a complex subject. After the course, most participants (38%, n = 192) rated their responsibility as 8, indicating a more realistic self-assessment rather than a reduction in dedication.

The results from this study align with our previous Caribbean Climate and Health Responders course, which demonstrated positive changes in knowledge, communication skills, and confidence in engaging with climate initiatives [35]. However, while the first course focused primarily on foundational knowledge (eight sessions) followed by five separate skills-based sessions, the current course was designed to strengthen action-oriented skills by integrating regional case studies into every main lecture. This approach ensured that participants engaged with real-world challenges and solutions, enabling them to discover successful climate adaptation and mitigation strategies within health systems. Additionally, the current course also attracted participants from a broader range of countries, which suggests that this model of education is generalizable beyond the region. While the previous study involved 132 participants who completed both pre- and post-course surveys, this course engaged 505 participants under similar conditions. This significant increase in participation underscores the growing recognition among health professionals of climate change as a critical issue and the need for specialized training to address this emerging challenge. In addition, the final exam results indicate that a majority of participants successfully demonstrated their knowledge and understanding of the course content.

An important lesson learned to be considered when managing an extensive program involves the challenge of providing personalized support to a diverse group of learners and ensuring participants have easy access to materials. The WhatsApp group became crucial for quick communication, as participants often overlooked weekly emails containing session details, slide decks, additional reports, and prerecorded sessions—potentially due to spam filters. The WhatsApp group facilitated two-way communication, allowing both course coordinators and participants to stay connected and engaged effectively.

In summary, the course effectively enhanced participants' skills due to its rigorous, evidence-based curriculum and timing, which fit well with health professionals' schedules. The course promoted active learning through interactive sessions and discussions, and it was tailored to the Caribbean context with regional experts. Engagement was further supported by a WhatsApp group that provided reminders, shared materials, and facilitated direct interaction with course coordinators. These factors collectively contributed to the practical application of the course content.

In summary, the course has demonstrated significant success in enhancing participants' awareness, communication skills, and preparedness regarding climate change. By providing a rigorous, evidence-based curriculum tailored to the Caribbean context and incorporating interactive learning methods, the course effectively deepened participants' understanding of climate change's direct relevance to their professional practice. The increase in readiness and the improvement in participants' sense of professional responsibility underscore the course's impact.

The findings highlight the importance of ongoing, specialized training for health professionals to address climate-related challenges effectively. As the course attracted a larger and more diverse group compared to previous iterations, its broader applicability and success in improving knowledge and skills are evident. Future efforts should focus on expanding the course's reach, continuously updating content, and tailoring training to specific regional challenges. By building on these strengths and addressing areas for improvement, the course can continue to play a crucial role in preparing health professionals to confront the evolving impacts of climate change.

Given the success of the course in improving awareness, communication skills, and preparedness, the following recommendations and learnings may be used to inform future training of health professionals:

1. Continue to build and promote action-oriented, evidence-based curricula, incorporating the latest climate science and practical strategies for addressing climate impacts. Regularly update the content to reflect new research and emerging best practices.

2. Since effective communication is critical, and many participants initially lacked formal training in this area, integrating more extensive modules or extra webinars on communication strategies related to climate and health should be considered.
3. To better address the specific challenges faced by different health systems and communities, tailor preparedness training to local contexts. Include case studies and examples relevant to the region's unique climate challenges.
4. Continue using successful engagement strategies, such as interactive online sessions, local expert lecturers, and supportive communication channels like WhatsApp groups to enhance learning and participation.
5. Encourage participants to seek further training and professional development opportunities in climate and health to deepen their expertise and maintain their readiness to address climate-related challenges.
6. Continue to build regional networks of public, private and academic partners to maximize reach and applicability of course content, recognizing that an interdisciplinary response is necessary for successful health adaptation and mitigation.

5. Limitations

An important limitation to recognize is the self-selection of participants into the course and into the study cohort. Though the course was widely promoted and open to all health professionals,

students, or interested individuals, it was primarily advertised through pre-existing organizations focused on climate and which may have inadvertently selected individuals already engaged with or particularly willing to engage in climate change and health related initiatives and education.

A significant number of registrants (2,075) did not complete the post-course survey, which could limit the generalizability of the results. The analysis was based on data from 505 participants who completed both the pre- and post-course surveys, which could introduce selection bias. Additionally, the longitudinal survey and end-of-course exam relied on self-reported data, potentially influenced by participants' subjective perceptions and not fully reflecting actual improvements in knowledge and skills. However, the fact that 75% (n = 379) of participants of whom 72% (n = 273) had no prior training were still able to pass the final exam suggests that they did gain significant knowledge. Lastly, the online Zoom format of the course likely selected for individuals who had consistent internet access and were available during the time the courses were offered. In countries lacking consistent internet service or where Zoom is not enabled— potential participants were unable to engage.

6. Conclusion

Health professionals occupy a critical position in the response to climate change, including climate mitigation and adaptation, and their professional expertise and roles as health messengers are currently under-employed in our society-wide response to this crisis. Live-virtual, evidence and competency-based regionally specific courses have the potential to change health professional behaviors toward addressing climate impacts on health.

Supporting information

S1 Text. Didactic curriculum: Caribbean climate and health responder course - education for action.
(DOCX)

S2 Text. Questionnaire applied to participants.
(DOCX)

S1 Table. All countries of residence for course registrants and final survey participants.
(XLSX)

S2 Table. Longitudinal survey answers and analyses.
(XLSX)

Acknowledgments

Dr Karen Polson-Edwards, Climate and Health Advisor, Pan American/World Health Organization.

Author contributions

Conceptualization: Cecilia Sorensen, Haley Campbell, Christopher Oura, James Hospedales.

Data curation: Haley Campbell, Nicola Hamacher, Jessica Patel.

Formal analysis: Nicola Hamacher, Jessica Patel.

Investigation: Cecilia Sorensen, Paula Henry.

Methodology: Cecilia Sorensen, Danielly de Paiva Magalhães, Haley Campbell, Nicola Hamacher, Jessica Patel, Paula Henry.

Project administration: Cecilia Sorensen.

Supervision: Cecilia Sorensen, Danielly de Paiva Magalhães, Haley Campbell, Paula Henry, James Hospedales.

Validation: Cecilia Sorensen, James Hospedales.

Visualization: Nicola Hamacher.

Writing – original draft: Danielly de Paiva Magalhães, Nicola Hamacher, Jessica Patel.

Writing – review & editing: Cecilia Sorensen, Danielly de Paiva Magalhães, Haley Campbell, Nicola Hamacher, Paula Henry, Christopher Oura, James Hospedales.

References

1. World Health Organization. Climate change and health [Internet]; 2023 [cited 2024 Sep 12]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
2. Kjellstrom T, Freyberg C, Lemke B, Otto M, Briggs D. Estimating population heat exposure and impacts on working people in conjunction with climate change. Int J Biometeorol. 2018;62(3):291–306. https://doi.org/10.1007/s00484-017-1407-0 PMID: 28766042
3. Méndez-Lázaro PA, Pérez-Cardona CM, Rodríguez E, Martínez O, Taboas M, Bocanegra A, et al. Climate change, heat, and mortality in the tropical urban area of San Juan, Puerto Rico. Int J Biometeorol. 2018;62(5):699–707. https://doi.org/10.1007/s00484-016-1291-z PMID: 27981339
4. World Meteorological Organization. State of the climate in Latin America and the Caribbean 2023. United Nations: Erscheinungsort nicht ermittelbar; 2024. 1 p.
5. Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, et al., editors. Climate change 2021: the physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change. IPCC; 2021.
6. Ebi KL, Lewis ND, Corvalan C. Climate variability and change and their potential health effects in small island states: information for adaptation planning in the health sector. Environ Health Perspect. 2006;114(12):1957–63. https://doi.org/10.1289/ehp.8429 PMID: 17185291
7. Gostimirovic M, Novakovic R, Rajkovic J, Djokic V, Terzic D, Putnik S. The influence of climate change on human cardiovascular function. Arch Environ Occup Health. 2020;75(7):406–14.
8. Akpinar-Elci M, Olayinka O. The impact of climate change and air pollution on the Caribbean. In: Akhtar R, Palagiano C, editors. Climate change and air pollution [Internet]. Cham: Springer International Publishing; 2018 [cited 2024 Oct 12]. p. 349–60. (Springer Climate). Available from: http://link.springer.com/10.1007/978-3-319-61346-8_21
9. Lowe R, Gasparrini A, Van Meerbeeck CJ, Lippi CA, Mahon R, Trotman AR, et al. Nonlinear and delayed impacts of climate on dengue risk in Barbados: a modelling study. PLoS Med. 2018;15(7):e1002613. https://doi.org/10.1371/journal.pmed.1002613 PMID: 30016319
10. PAHO/EIH Open Data. PLISA health information platform in the Americas [Internet]; 2020 [cited 2024 Oct 12]. Available from: https://opendata.paho.org/en
11. Fernandez G, Baum N. American association for physician leadership - inspiring change. Together; 2022 [cited 2024 Oct 12]. Mental Health of Puerto Ricans Living On and Off the Island After Hurricane Maria. Available from: https://www.physicianleaders.org/articles/mental-health-puerto-ricans-living-off-island-after-hurricane-maria

12. Eisenberg MC, Kujbida G, Tuite AR, Fisman DN, Tien JH. Examining rainfall and cholera dynamics in Haiti using statistical and dynamic modeling approaches. Epidemics. 2013;5(4):197–207.
13. De Jesus Crespo R, Wu J, Myer M, Yee S, Fulford R. Flood protection ecosystem services in the coast of Puerto Rico: associations between extreme weather, flood hazard mitigation and gastrointestinal illness. Sci Total Environ. 2019;676:343–55.
14. Escobedo AA, Almirall P, Rumbaut R, Rodríguez-Morales AJ. Potential impact of macroclimatic variability on the epidemiology of giardiasis in three provinces of Cuba, 2010–2012. J Infect Public Health. 2015;8(1):80–9.
15. Cruz-Cano R, Mead EL. Causes of excess deaths in Puerto Rico after Hurricane Maria: a time-series estimation. Am J Public Health. 2019;109(7):1050–2. https://doi.org/10.2105/AJPH.2019.305015 PMID: 30998411
16. Jafino BA,Walsh B, Rozenberg J, Hallegatte S. World Bank. Revised estimates of the impact of climate change on extreme poverty by 2030. [cited 2024 Oct 12]. Available from: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/706751601388457990/Revised-Estimates-of-the-Impact-of-Climate-Change-on-Extreme-Poverty-by-2030
17. Ebi KL, Hess JJ. Health risks due to climate change: inequity in causes and consequences: study examines health risks due to climate change. Health Aff (Millwood). 2020;39(12):2056–62.
18. Robinson S ann, Wren C. Geographies of vulnerability: a research note on human system adaptations to climate change in the Caribbean. Geogr Tidsskr-Dan J Geogr. 2020;120(1):79–86.
19. Green Climate Fund. Developing a climate resilient health system in the Bahamas [Internet]; 2021 [cited 2022 Aug 28]. Available from: https://www.caribbeanclimate.bz/gcf/2021/05/14/elementor-3659/
20. Shaman J, Knowlton K. The need for climate and health education. Am J Public Health. 2018;108(S2):S66–7. https://doi.org/10.2105/AJPH.2017.304045 PMID: 29072939
21. Health and climate change at the 77th World Health Assembly [Internet]. [cited 2024 Oct 12]. Available from: https://www.who.int/news-room/events/detail/2024/05/27/default-calendar/climate-health-events-at-wha77
22. Mazumder H, Hossain MM. Climate change education for health-care professionals: crucial gaps in low-income and middle-income countries. Lancet Planet Health. 2024;8(4):e216. https://doi.org/10.1016/S2542-5196(24)00010-X PMID: 38580422
23. Intergovernmental Panel On Climate Change (Ipcc). Climate change 2022 – impacts, adaptation and vulnerability: working group II contribution to the sixth assessment report of the intergovernmental panel on climate change [Internet]. 1st ed. Cambridge University Press; 2023 [cited 2024 Oct 12]. Available from: https://www.cambridge.org/core/product/identifier/9781009325844/type/book
24. General assembly supports Antigua and Barbuda Agenda for small Island developing states, decides modalities of world social summit, adopting three texts | meetings coverage and press releases [Internet]. [cited 2024 Oct 12]. Available from: https://press.un.org/en/2024/ga12615.doc.htm
25. 2021 WHO health and climate change global survey report. 1st ed. Geneva: World Health Organization; 2021. 1 p.
26. Sistermans IJ. Integrating competency-based education with a case-based or problem-based learning approach in online health sciences. Asia Pacific Educ Rev. 2020;21(4):683–96. https://doi.org/10.1007/s12564-020-09658-6
27. Knowles MS, editor. Andragogy in action. 1st ed. San Francisco: Jossey-Bass; 1984. 444 p. (The Jossey-Bass management series).
28. Vygotsky LS. Mind in society: development of higher psychological processes [Internet]. In: Cole M, Jolm-Steiner V, Scribner S, Souberman E, editors. Harvard University Press; 1980 [cited 2025 Apr 1]. Available from: http://www.jstor.org/stable/10.2307/j.ctvjf9vz4
29. Sorensen C, Campbell H, Depoux A, Finkel M, Gilden R, Hadley K, et al. Core competencies to prepare health professionals to respond to the climate crisis. PLOS Clim. 2023;2(6):e0000230. https://doi.org/10.1371/journal.pclm.0000230
30. Verstegen DML, De Jong N, Van Berlo J, Camp A, Könings KD, Van Merriënboer JJG, et al. How e-Learning can support PBL groups: a literature review. In: Bridges S, Chan LK, Hmelo-Silver CE, editors. Educational technologies in medical and health sciences education [Internet]. Cham: Springer International Publishing; 2016 [cited 2025 Apr 1]. p. 9–33. (Advances in Medical Education; vol. 5). Available from: https://link.springer.com/10.1007/978-3-319-08275-2_2
31. Drewry J, Oura CAL, Adams S, Bayley L, Kotcher J, Ivey M. Public understanding of climate change and health in the Caribbean: results and recommendations from a 10-country perceptions survey. J Clim Change Health. 2022;6:100155. https://doi.org/10.1016/j.joclim.2022.100155
32. De Freitas L, Bahadursingh S, Basdeo D, Kotcher J, Hospedales J. Caribbean health professional views on climate change and health. J Clim Change Health. 2023;12:100248. https://doi.org/10.1016/j.joclim.2023.100248
33. Maibach E, Frumkin H, Ahdoot S. Health professionals and the climate crisis: trusted voices, essential roles. World Med Health Policy. 2021;13(1):137–45. https://doi.org/10.1002/wmh3.421
34. Rise N, Oura C, Drewry J. Climate change and health in the Caribbean: a review highlighting research gaps and priorities. J Clim Change Health. 2022;5:100126.
35. Sorensen C, Hamacher N, Campbell H, Henry P, Peart K, De Freitas L, et al. Climate and health capacity building for health professionals in the Caribbean: a pilot course. Front Public Health. 2023;11:1077306. https://doi.org/10.3389/fpubh.2023.1077306 PMID: 36778561