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Review

Tailoring climate–health competencies for diverse health cadres: Findings from a scoping review

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ABSTRACT

Introduction: Climate change poses a growing global health threat, disproportionately affecting low- and middle-income countries (LMICs) with fragile health systems and limited adaptive capacity. The health workforce plays a critical role in managing climate-sensitive health risks but often lacks adequate training. Building climate-resilient health systems therefore requires equipping health workers with the relevant knowledge, skills, and adaptive capacities. The goal of this review was to synthesize existing literature to inform the creation of a climate-health competency framework appropriate for a diverse health workforce.

Methods: A scoping review was conducted to examine climate–health competency frameworks across peer-reviewed and grey literature, institutional reports, and global policy documents. Frameworks were analyzed for geographic origin, scope, workforce role differentiation, and contextual applicability, with particular attention to LMIC relevance. This was followed by framework construction as described below.

Results: Most existing frameworks originated from high-income countries (HICs) and presuppose strong institutional capacity, digital infrastructure, and governance systems—conditions not typical in LMICs. Furthermore, they rarely distinguish competencies across different health workforce roles, limiting practical implementation. From the synthesis, a consolidated KSTCP framework was derived, encompassing five domains: Knowledge, Systems Thinking, Technical Skills, Communication and Leadership, and Practice. Two major gaps were identified: (1) limited LMIC-specific frameworks, and (2) insufficient role differentiation. To address these, a cadre-specific competency set was developed for clinical, public health, and community health workers, aligned with their distinct functions in service delivery and community engagement.

Conclusion: The proposed framework provides actionable, context-sensitive guidance for educators, policymakers, and development partners to strengthen health workforce capacity for climate resilience. It offers globally relevant competencies that differentiate workforce roles to support effective implementation, with particular significance for LMICs, where capacity constraints make targeted workforce development especially important. Implementing cadre-specific climate–health competencies can enhance preparedness and adaptive responses within climate-vulnerable health systems.

1. Introduction

The implementation of policies and strategies to address the health impacts of climate change hinges critically on the health workforce. Climate-health resilience demands a different skill set—one that integrates public health, ecology, disaster preparedness, communication, and health equity. It requires health professionals to be able to interpret climate data, assess vulnerability in diverse populations, respond to climate-induced emergencies, and implement sustainable practices within their institutions [1]. Thus, while existing health workforce competencies may provide a foundation, they are insufficient to meet the complex and evolving challenges posed by climate change. This gap highlights the importance of identifying and strengthening the core competencies needed by public health officials and their partners to operate effectively in the dynamic and intersectoral contexts of LMIC health systems responding to climate change [2].

Health and climate strategies envisage a collaborative, cross-disciplinary approach involving governments, non-governmental organizations, development partners such as donor agencies and international technical bodies, as well as health professional schools, healthcare

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Table 1 (*continued*)

Source (Year)	Source type	Geographic scope or focus	Target audience	Competency themes	Inferences for training methods and approaches	Inferences for evaluation mechanisms (Program or Learner assessment)
Yeboah et al. (2024) [7]	Systematic review on perceptions, attitudes and perspectives of nurses (mixed-method approach)	International – evidence synthesized from 9 countries across 5 continents	Nursing students and professionals, nurse educators, and healthcare leaders/ policymakers involved in embedding sustainability into health system	Five key themes were identified: i) knowledge and awareness of climate change, ii) link between nursing and climate change, iii) environmental sustainability, iv) barriers to environmentally responsible healthcare, and v) routes to environmentally sustainable nursing practices.	Highlights the need for integrating climate change and sustainability into nursing curricula, Continuous Professional Development, and professional development. Calls for healthcare organizations and professional bodies to actively provide tailored education (beyond reliance on media)	Not applicable
Armand et al. (2024) [46]	KAP style survey based (post-intervention)	Based on single academic medical center in Boston, Massachusetts, United States of America	Clinicians (physicians and psychologists) who completed the Quality Incentive Program; findings valuable to academic medical center leadership and clinician educators designing climate-health incentive programs	Understanding of climate-health impacts; perceived personal and clinical relevance; attitudinal shifts post-training	Climate-health video modules, delivered through an incentive program, were well-received and seen as relevant, especially by clinicians in climate-facing specialties—highlighting the value of tailoring by specialty	Not applicable
Igarashi et al. (2024) [17]	KAP survey (Quantitative); 1100 participants	National - Japan	Physicians (as the survey population) — findings intended to inform medical educators, professional training bodies, and policymakers to support enhanced climate–health education and resources	Assessed knowledge; awareness of responsibility; advocacy readiness; lack of knowledge, formal training, and institutional resources identified as major barriers	Emphasizes urgent need for integrated climate–health education in medical school and continuing professional development. Need to build institutional support and resources to enable climate-specific advice and advocacy (e.g., training modules, patient communication tools)	Not applicable

the premise that health workers must be equipped to navigate uncertain, complex, and evolving challenges, such as extreme weather events and other climate-related disruptions. In line with this, the frameworks emphasize both 'what the health workforce needs to know' and 'what they need to be able to do and deliver' in real-world contexts, aiming to develop both conceptual understanding and practical competence, including adaptive thinking, systems understanding, and scenario-based decision-making.

Based on the full range of competencies described in the literature included in our review, we have synthesized the required competencies thematically and classified them broadly into the 'KSTCP framework' consisting of five domains – Knowledge (K), Systems Thinking (S), Technical Skills (T), Leadership and Communication (C), and Professional Practice (P) (Table 2). The Knowledge domain captures *what health professionals need to know*, including scientific foundations and contextual awareness. Systems thinking represents *how to think*, emphasizing the ability to recognize interconnections, complexity, and upstream drivers of health risks. Technical skills reflect *how to analyze*, encompassing research, critical appraisal, and the application of evidence for decision-making. Communication and leadership highlight *how to work with others*, drawing on skills of advocacy, negotiation, and interdisciplinary teamwork. Finally, the Practice domain captures *how to act*, including professional conduct, sustainable healthcare practices, and preparedness in the face of climate-related crises. Although classified into distinct domains, the competencies often interconnect, with skills in one area complementing or enabling those in another as discussed in the next section.

Some of the competencies discussed —such as interprofessional collaboration, surveillance, and emergency preparedness—exist within current health training programs but must be reoriented with a climate-specific lens. This involves adapting these competencies to reflect how climate change reshapes health risks and operational demands; for example, surveillance training would extend beyond routine disease monitoring to include climate-sensitive threats such as heat-related illnesses, vector-borne diseases, or air-quality–related respiratory conditions. Others, such as climate-health literacy, systems-based clinical reasoning, and understanding the environmental impact of healthcare decisions, are entirely new. This combination of adapted and emerging competencies underscores the need for training programs to update existing content and incorporate emerging topics that address the complex challenges posed by climate change and health.

3.1.1. *Knowledge*

Building a strong foundational understanding of the linkages between climate and health among health professionals was the most common capacity-building aspect highlighted throughout the literature (Table 1). Equipping health professionals with knowledge about climate-resilient health systems and climate-sensitive health risks strengthens cognitive processes and drives behavior change. A strong knowledge base also enables individuals to apply knowledge effectively and develop the competency to act, including designing and implementing interventions [2]. Also, knowledge building in climate-health is an evolving process - starting from foundational climate science, progressing to clinical relevance, and extending to policy context [8]. This staged approach highlights the importance of continuing medical education and professional development, ensuring that as health

Table 2
Competencies identified for dealing with health impacts of climate change.

Competencies	Brief description	Broad domains identified
Understanding scientific evidence linking climate change to health	Climate science fundamentals like ability to explain climate vs. weather, greenhouse gas effects, anthropogenic warming; direct and indirect impact on health; ability to identify how human activities in the Anthropocene (e.g., fossil fuel use, agriculture, urbanization, land-use change) drive environmental changes that cascade into health impacts	Knowledge (K)
Approaches for dealing with climate change	Mitigation, Adaptation, Resilience and Co-benefits	
Equity and justice	Global health inequalities; vulnerable populations (e.g., children, marginalized groups); environmental justice; climate and health equity principles	
Policy context awareness	Awareness of local/regional/global agreements and policies; collective action strategies	
Environmental and resource stewardship	Understand the environmental impacts of healthcare systems, including carbon footprint and waste; principles of sustainable healthcare and strategies for efficient resource use	
Mapping interconnections and vulnerability analysis	Mapping interdependencies across ecological, social, and health systems. Ability to recognize how systemic factors (structural racism, poverty, governance, global inequalities) create uneven health risks from climate change	Systems thinking (S)
Integrated planning	Applying knowledge of multiple pathways to plan, evaluate, and coordinate climate–health actions at individual, community, and policy levels	
Risk assessment and early warning	Recognize early warning signs and emerging threats; vulnerability assessments; hazard-specific knowledge (infectious, chemical, natural)	Technical Skills (T)
Research and critical thinking	Scientific inquiry, research design, analysis, evaluation, and planning for climate–health interventions	
Evidence-based decision making	Interpret projections, assessments, and risk management frameworks; monitoring and evaluation	
Communication skills	Develop and deliver public climate–health campaigns; knowledge translation; clear risk communication; community engagement skills	Communication and Leadership (C)
Advocacy	Policy advocacy; community mobilization; movement building; framing messages for different audiences	
Negotiation and influence	Dialogue, negotiation, influence, and interpersonal engagement	
Interdisciplinary collaboration	Work across disciplines; mobilize community partnerships; transdisciplinary project design	
Leadership and governance	Ethical and inclusive leadership; equity-focused preparedness; organizational and policy governance roles	
Mentorship and capacity building	Train and mentor peers; support curriculum integration; develop student-led initiatives	
Organizational change	Healthcare systems management; quality improvement; sustainability leadership in healthcare institutions	
Integration in clinical practice	Recognizing climate-sensitive diseases in diagnosis, or counselling patients on heat, air pollution, or vector exposure.	Practice (P)
Ethical responsibility and professional conduct	Fairness and justice; professional ethics; advocacy responsibilities of health professionals	
Sustainable healthcare practice	Model low-carbon behaviours; engage in workplace sustainability efforts; lead eco-practice initiatives	
Emergency preparedness and crisis response	Infection prevention and control; protective equipment use; prioritize vulnerable populations during crises	
Resilience and reflexivity	Build personal and team resilience; reflective practice; adaptability to climate-related stressors	

Source: Developed by Authors based on literature identified in Table 1.

professionals progress in their careers, their knowledge base keeps pace with their expanding roles and responsibilities.

Additionally, the integration of climate-health knowledge into medical education is increasingly recognized as essential for preparing future clinicians. For instance, the Association for Medical Education in Europe (AMEE) and the Association of Schools of Public Health in the European Region (ASPHER) provide comprehensive guidance on integrating core climate-health science topics into health professional education curricula in line with their institutional mandates [9,10]. Other authors bring their own disciplinary emphasis on the types of knowledge that need to be included in training programs. For instance, the Planetary Health Education Framework (PHEF) focused on planetary boundaries and ecosystem-health relationships as a key area for knowledge building [11]. Similarly, Rabinowitz et al. 2017 look at this from a One Health perspective emphasizing competencies to collectively deal with animal, environmental and human health systems. They highlight the need for professional skill development to be underpinned by knowledge of ecosystem function and health, food systems, and the ethical dimensions of human–animal–environment interactions [12].

KAP studies included in the review reveal that existing knowledge about climate-health linkages is inadequate among health professionals. For instance, KAP surveys in India and China showed that even where there is awareness of direct health effects (such as heat, extreme weather, air pollution), it is absent for indirect or delayed impacts such as malnutrition, mental health, migration, conflict or social instability [13,5]. Sometimes health professionals' personal experiences affect how they perceive climate change: students in western and eastern regions of China were more likely to recognize climate change as a local community concern, likely due to personal exposure to extreme weather events [13]. Even in high-resource settings, physicians report limited formal

training and a knowledge gap. Valois et al. (2016) found that many physicians in Canada lacked sufficient understanding of climate–health to guide patient care, underscoring a need for Continuing Medical Education (CME) [14].

3.1.2. Systems thinking

Another critical theme across the reviewed literature is the need for health professionals to understand, interpret, and respond to the complexity of interlinked environmental, social, and health systems. This competency involves recognizing the cascading effects of climate change across multiple sectors and scales, as well as understanding the institutional and governance structures that influence health outcomes. Jagals & Ebi (2021) highlight the importance of systems-level preparedness and resilience in health systems, emphasizing training that equips professionals to anticipate and address systemic vulnerabilities [2]. PHEF pushes this idea further by situating learners within wider ecological and governance systems, encouraging them to think across scales—from global boundaries down to local, community-level responses.

Systems thinking is essential not only for understanding the root causes of vulnerability but also for designing equity-oriented interventions that advance health and climate resilience, which is less often described in the literature. Kline et al. (2024) takes a step in this direction and emphasize competencies that prioritize critical and systems thinking, enabling learners to analyze how structural racism, discrimination, and environmental injustice generate unequal exposures to pollutants, climatic extremes, and healthcare access barriers in marginalized communities [15].

Additionally, as noted previously, the KAP surveys point out that health professionals tend to recognize the direct and immediate health effects of climate change but are less certain about the indirect or delayed health impacts. This also indicates the need for stronger systems thinking skills—skills that help connect the dots across social, economic, and environmental domains.

3.1.3. Technical skills

Beyond theoretical knowledge, the literature consistently shows that climate–health education and training programs must cultivate technical and analytical skills that allow health professionals to move from awareness to action. One recurring theme is the ability to conduct risk and vulnerability assessment by integrating climate, biophysical, and socioeconomic data to identify at-risk populations, which is also a priority across climate and health programs across countries.

Another is to build capacity for development and use of early warning systems, alongside the ability to collect, manage, analyze, and disseminate climate–health data. Sambath et al. (2022), in their survey of the Indian health workforce, found relatively strong familiarity with air pollution monitoring but weak preparedness around heat action plans, reflecting uneven technical capacity across climate hazards [5].

Closely linked is the need for research and critical thinking skills. Sorensen and Fried (2024) emphasized that physicians must be trained to critically appraise emerging climate–health evidence and translate it to local clinical contexts [16]. Building on this, Lemery et al. (2024) highlight the importance of applying interdisciplinary research skills that bridge climate science, epidemiology, and health systems [8].

3.1.4. Communication and leadership

Because climate change affects health across multiple levels—patients, communities, and institutions—communication and collaboration emerge as core competencies for health professionals. Communication skills are essential for explaining climate-related health risks to patients, engaging communities, informing colleagues, and influencing decision-makers. Relatedly, many frameworks stress that health professionals have a responsibility to speak out on climate and health, highlighting public health advocacy skills. Yet communication is often hindered by structural barriers such as limited knowledge, resources, and confidence, as well as psychological barriers like a lack of conviction in their own ability to effect change. In Japan, for instance, over half of the physicians surveyed cited lack of resources as an obstacle to climate-specific advice [17], while a global survey found nearly one in three professionals doubted their engagement would make a difference [4].

Beyond individual communication, effective action requires collaboration across levels. At the institutional level, nursing scholarship recommends involving nurses in shaping hospital procurement and service design to promote greener practices [7]. Similarly, at Harvard Medical School, students and faculty collaborated to design a climate–health curriculum that was later integrated across the four-year program—an example of partnership translating into lasting educational change [15]. At the system level, interdisciplinary collaboration between clinicians, public health experts, environmental scientists, and policymakers is critical, with cross-sector partnerships particularly important for community-based responses [16]. From the literature, we surmise that coordination and collaboration are critical for implementing best practices in preparedness planning, vulnerability assessments, stress testing, and educational outreach. They are also essential for aligning policies, mobilizing resources, exchanging knowledge, engaging communities, and developing effective monitoring and evaluation systems.

Taken together, these communication and collaboration skills form the foundation of climate–health leadership. The AMEE (2021) consensus statement introduces the idea of 'eco-ethical leadership,' which integrates ecological sustainability with values of justice, collaboration, advocacy, and activism [10]. Taken together, the reviewed literature suggests that leadership in the climate-health context extends beyond authority, encompassing the capacity to mobilize diverse actors, bridge disciplinary divides, and advocate for equitable, sustainable solutions.

3.1.5. Practice

All the domains and competencies discussed so far underpin the everyday practice and effective implementation of climate-health strategies by health workforce cadres. For instance, competencies mentioned in previous domains drive practice by giving health professionals the evidence and understanding they need to recognize climate-related health risks, make informed decisions, and apply the right interventions in real-world settings. Collectively, these competencies emphasize that professional practice in climate-health extends beyond individual patient care, encompassing leadership, accountability, educational roles, and engagement with broader systems to effectively address the multifaceted health impacts of climate change.

Health professionals, especially clinicians, are expected to apply evidence-based knowledge to anticipate and manage climate-driven health risks, particularly among vulnerable populations, reflecting an ethical commitment to equity and patient-centered care, which is an important competency to be developed [18,8].

Sustainable healthcare practice is another recurring theme in the review, with studies underscoring the role of health professionals in modelling low-carbon behaviors and championing sustainability initiatives, within institutions and communities. Preparedness for emergencies and crises is also widely discussed, particularly competencies in infection prevention and control, appropriate use of personal protective equipment, and prioritization of vulnerable populations during climate-related events.

3.2. Use of competency frameworks in designing training programs

The competency frameworks that are described in the literature are intended to be used by academic institutions, public health schools, and professional associations to guide the development of curricula, training modules, and faculty development programs that seek to integrate climate considerations in their health training programs. Indeed, several

of them have been used to inform curriculum reforms and revisions in medical and nursing schools globally. For example, at the University of Minnesota School of Nursing, faculty have systematically mapped the Planetary Health Education Framework's domains to nursing competencies and developed specific learning outcomes and implemented them in their curricula [19].

We note, however, that operational training of health professional cadres functioning in resource-constrained settings is rarely a critical consideration in the design of competency frameworks. The process of adapting these frameworks in various contexts can itself reveal the need for additional capacities, especially among educational institutions and health professional regulators in LMIC. In South Africa, for example, a national Delphi panel of health professions educators evaluated AMEE's recommendations to align them with the AfriMEDS competency framework [20]. This contextual adaptation process underscored the need for regionally relevant competencies that reflect local health system demands and training realities. It also identified the key barriers to implementation, such as limited faculty capacity and curriculum overload in the African context. Such studies can be especially useful in providing practical insights to planners and decision-makers but are under-represented in the literature.

Global initiatives have sought to bridge competency gaps by moving from frameworks to applied training. Examples include educational and training programs led by the Global Consortium on Climate and Health Education (GCCHE), the Medical Society Consortium on Climate and Health, the Lancet Countdown, the International Federation of Medical Students' Associations, and the University of California San Francisco. For instance, the GCCHE developed Responder Courses delivered online across multiple regions. These courses, created in collaboration with global academic institutions, climate scientists, and public health experts, focus on practical, systems-based competencies tailored to local climate-health vulnerabilities. The courses can function as stand-alone resources or be embedded into institutional programs [1,21]. Additionally, the GCCHE partnered with organizations in the United States to implement a train-the-trainer model through the ECHO course [22]. The 6-month follow-up showed participants were actually applying what they learned (teaching others, starting courses, etc.) [22].

While such initiatives are expanding, there is a pressing need for similar initiatives, particularly in low- and middle-income countries (LMICs) where the health impacts of climate change are already apparent and resources are limited. As nations begin translating their health and climate strategies into actionable programs, health policymakers and practitioners in LMICs increasingly need guidance on designing context-specific operational training for health workers implementing these programs. It is also important to consider the broader context in which different health systems operate. In many LMICs, limited budgets, gaps in routine data, and constrained decision-making space at decentralized levels shape what competencies are realistically useful. In such settings, it may be more practical to prioritize core operational and analytic skills, while more advanced capabilities such as predictive modelling can be introduced gradually as system capacity grows. Indeed, this ability for contextual adaptation, based on the design, needs, and capacities of the health system is among the critical skills required for climate and health planners and policymakers.

3.3. Competency mapping by health workforce cadre and distinct roles

A single, standardized curriculum cannot meet the diverse learning needs of all health cadres [8]. National and subnational policies on health and climate change assign different roles to health workers depending on the functions they perform, and capacity-building must reflect the unique responsibilities and scope of each cadre.

The clinical workforce focuses on patient-level care, requiring competencies such as climate-informed diagnostics and treatment, management of climate-sensitive conditions, low-carbon healthcare practices, patient-centered advocacy for co-benefits, facility resilience and preparedness, integration of climate considerations into clinical decision-making, and effective risk communication with patients. The public health workforce operates at a population level, necessitating systems-level competencies such as climate-linked surveillance, risk assessments, and translation of findings into policy. The community health workforce functions at the grassroots, prioritizing outreach, local adaptation, and cross-sectoral resource mobilization.

Because clinical, public health, and community health cadres perform distinct functions at different levels of the health system, we mapped the climate-health knowledge, attitudes, and skills identified in the literature to each cadre's typical scope of practice. Based on this mapping, we assigned the most relevant skills and competencies to each cadre and classified them along the five domains (Table 3). While all cadres require competency-building across each domain, the specific skills and focus vary. This categorization enables a clearer synthesis of which competencies are emphasized for which cadres and supports a more targeted approach to workforce development.

3.4. Approaches to delivering climate-health training

Although reviewing training methods and approaches was not the primary objective of our study, we highlight some relevant observations that emerged. Evidence on the most effective training methods remains limited, particularly in LMIC contexts.

3.4.1. Digital and in-person training

Through this review, we found that virtual modalities are emerging as the primary mode of imparting training for the climate-health workforce. These sessions are often asynchronous and self-paced, usually followed by a quiz, question and answer sessions and self-reflection exercises, aiming to reinforce learning [21,23–25]. In addition, some of these training programs also include practice sessions based on clinical cases, helping learners contextualize climate-health connections in real-world decision-making [21,25]. Courses that blended diverse academic perspectives, encouraged dialogue among voices from across the health sectors, and incorporated communication-focused group work were found to be most effective [26].

Evidence from Atta et al. (2025) supports digital modules for strengthening climate-related nursing competencies, particularly in underserved rural settings [27]. Participants showed statistically significant gains on the Climate Change Knowledge Questionnaire, Environmental Self-Efficacy Scale, and Pro-Environmental Behavior Scale, highlighting the effectiveness of online education in building practical and attitudinal competencies. Reviews of continuing medical education confirm this trend, showing that climate-related CME programs are nearly exclusively online, mostly self-paced, with a few live or hybrid offerings [28]. Digital training offers flexibility and scalability, particularly valuable for geographically dispersed or resource-limited health systems. However, this should be tested more in different LMIC contexts, where limited access to digital technology could make it harder for people to use these resources.

In-person and experiential training remain essential for developing hands-on clinical skills, decision-making, leadership, and attitudinal competencies, typically delivered through workshops, scenario-based sessions, simulations, and field exercises. However, we identified relatively few studies on such training, not because it is ineffective, but because it appears to be less systematically evaluated and documented in the published literature. In contrast, digital interventions are often novel, scalable, and easier to evaluate, offering automatic metrics for participation and learning outcomes. This, coupled with global initiatives and funding for e-learning platforms, has contributed to the prominence of online training in published studies.

3.4.2. Understanding needs and learning pathways

Different health workforce cadres access climate–health information through varying channels, a factor that policymakers must consider

Table 3
Competencies required across different health workforce cadres.

Health workforce cadre and their functions identified in climate and health policies and/or HNAPs	Specific competencies and skills identified
Public health workforce Governance and coordination, Risk and vulnerability assessment, Adaptation planning, Early warning and surveillance, Capacity building, Sustainable health operations, Monitoring and evaluation, Research and evidence.	Knowledge (K) • **Climate Science Literacy:** Understanding drivers of climate change • **Health Impacts**: Comprehensive knowledge of how climate change affects human health, including: ○ Direct Impacts: Heat-related illnesses, injuries, and deaths from extreme weather events. ○ Indirect Impacts: Changes in the spread of vector-borne (e.g., malaria, dengue) and water-borne diseases (e.g., cholera), impacts on food security and nutrition, and mental health effects. ○ Vulnerability: Identifying and analysing which populations are most vulnerable to these impacts (e.g., the elderly, children, low-income communities) ○ Policy awareness: Familiarity with health components of climate policies (HNAPs, NAPs, NDCs, Sendai Framework, Paris Agreement). ○ Health system context: Understand how climate change affects service delivery, supply chains, infrastructure, and workforce needs. Systems thinking (S) • **Health and Climate Policy Integration:** Integrate health into broader national climate change policies, such as NAPs and NDCs. • **Health System Resilience:** Understanding the concepts of climate-resilient health systems and learning how to apply them, from making health facilities more durable to strengthening surveillance systems for early detection of climate-sensitive diseases. Technical Skills (T) • **Risk & vulnerability assessment:** Use data (climate, epidemiological, socioeconomic) to identify local health risks and hotspots. • **Surveillance & early warning:** Strengthen systems to detect and track climate-sensitive diseases, hazards, and environmental exposures. • **Modelling & projections:** Apply scenario tools to anticipate future disease burdens and inform preparedness. • **Evaluation methods:** Design and evaluate interventions for effectiveness, efficiency, and equity impact. Communication and Leadership (C) • **Inter-sectoral Collaboration:** Training on how to work with non-health sectors like agriculture, water and sanitation, urban planning, and disaster management. This includes developing a shared language and understanding of each other's roles and responsibilities. • **Risk Communication:** Learning how to effectively communicate climate-related health risks to different audiences, including policymakers, clinical professionals, and the public. This involves tailoring messages to avoid panic and promote actionable behaviours. • **Advocacy:** Developing skills to advocate for the health sector's priorities and secure necessary resources for climate-related health initiatives. Practice(P) • **Conduct vulnerability and adaptation assessments: e.g.** use heat-mortality and demographic data to map urban heat–health risk zones; predictive modelling to anticipate local disease outbreaks (e.g., malaria spread due to changing rainfall). • **Implement monitoring & evaluation frameworks: e.g.** develop indicators to assess effectiveness of a dengue early warning system. Track resource allocation and coverage of adaptation interventions. Integrate climate–health indicators into national health information systems. • **Lead emergency preparedness and response: e.g.** coordinate multi-sector plans for flood response with health, water, and disaster agencies; develop surge capacity plans for health services during heatwaves or wildfire smoke events; prioritize rapid deployment of services for children, elderly, and marginalized populations during crises. • **Advance sustainable health operations: e.g. i**ntroduce solar energy systems in rural health centres to ensure climate-resilient power supply, promote hospital waste reduction and green procurement policies, implement climate-smart facility management (e.g., water harvesting, cooling efficiency, low-carbon transport). • **Monitor and evaluate national climate–health action plans and program: e.g.,** assess whether heat–health action plans are reducing hospital admissions. Identify gaps such as insufficient supplies for rural health facilities, produce evidence-based reports to inform ministries of health and environment, guiding procurements and resource prioritization
Clinical health workforce: Service delivery, Surveillance and reporting, Emergency preparedness, Patient adaptation advice, Equity in care, Sustainable operations, Capacity building, Advocacy	Knowledge (K) • **Climate–health literacy:** Understand how climate drivers (heat, air pollution, extreme weather, vector ecology) translate into patient-level conditions. • **Exposure history:** Know how to take and interpret environmental and occupational exposure histories in routine consultations. • **Vulnerability awareness:** Know which populations (elderly, children, chronically ill, marginalized) are most vulnerable and why. • **Policy awareness:** Be familiar with institutional protocols, climate–health guidelines, and sustainable care policies. Systems Thinking (S) • **Interconnections**: Ability to link clinical conditions with upstream

(*continued on next page*)

Table 3 (*continued*)

Health workforce cadre and their functions identified in climate and health policies and/or HNAPs	Specific competencies and skills identified
	environmental and social determinants. • **Equity lens**: Ability to incorporate justice and fairness into clinical prioritization, especially during crises. • **Resilient systems perspective**: Ability to recognize how resilient facilities, supply chains, and surveillance systems sustain patient care during shocks. Technical Skills (T) • **Risk assessment and early warning**: Ability to recognize and act on early signals of climate-sensitive conditions (e.g., dehydration, vector-borne fevers, respiratory illness spikes). • **Surveillance participation**: Ability to contribute to syndromic and sentinel surveillance of climate-sensitive illnesses. • **Clinical data reporting**: Ability to document and share anonymized patient data for monitoring, evaluation, and research. • **Evaluation methods**: Ability to assess effectiveness and equity of clinical interventions under climate stress. Communication and Leadership (C) • **Patient communication**: Ability to provide clear, tailored advice for adaptation (e.g. hydration, protective behaviours, safe food/water). • **Community engagement**: Ability to support public health education campaigns and outreach activities. • **Cross-sector coordination**: Ability to work with public health agencies, local authorities, and community partners during emergencies. • **Advocacy**: Ability to raise awareness and advocate for resources for climate-sensitive care. • **Mentorship**: Ability to guide junior staff and students in integrating climate–health into practice. Practice (P) • **Emergency response**: Ability to implement triage, referral, and treatment protocols during extreme weather events and disasters. • **Infection prevention & control:** Ability to apply these measures effectively in climate-related emergencies (floods, vector outbreaks, heatwaves). • **Sustainable healthcare practice**: Ability to apply low-carbon and resource-efficient practices (rational use of supplies, waste minimization, energy efficiency). • **Resilient patient care**: Ability to ensure continuity of care for vulnerable populations during climate-related disruptions. • **Operational contribution**: Ability to support institutional green initiatives, disaster preparedness, and climate-resilient facility operations.
Community health workforce: Local risk assessment, Early warning & communication, Community education, Surveillance support, Emergency preparedness, Sustainable household practices, Equity & advocacy, Feedback	Knowledge (K) • **Climate–health basics:** Understand local climate drivers (e.g., heat waves, cyclones, floods, droughts) and their direct health impacts (e.g., dehydration, injuries, malnutrition, water-borne diseases). • **Local risks and vulnerabilities:** Know which groups are most at risk — e.g., elderly people during heatwaves, pregnant women during food insecurity, children exposed to diarrheal diseases from unsafe water. • **Sustainable practices:** Know principles of safe water storage, use of mosquito nets, clean cooking fuels, and waste management to reduce household-level risks. • **Institutional protocols**: Be familiar with when and how to report health events — e.g., unexplained fever clusters (possible dengue/malaria), or diarrheal outbreaks after flooding. Systems Thinking (S) • **Recognizing interconnections**: Ability to recognize how environmental and social conditions shape health risks — for example, linking poor drainage to mosquito breeding, or deforestation to flooding and diarrheal disease outbreaks. • **Equity and justice orientation: E.g.,** Ability to recognize that households in informal settlements, with poor housing and sanitation, are at much higher risk during climate shocks. • **Community integration:** Ability to channel community voices into local governance — e.g., reporting that lack of safe shelters puts women and children at greater risk during cyclones. Technical Skills (T) • **Risk assessment**: Recognize hazards like heat stress in outdoor workers, food shortages after drought, or respiratory illnesses from wildfire smoke. • **Vulnerability assessment:** E.g., Identify families living in low-lying areas prone to flooding, or communities without reliable clean water supplies. • **Data contribution:** Record cases of fever, diarrheal disease, or malnutrition during seasonal changes for reporting to health authorities. • **Research contribution:** E.g., Participate in mapping of mosquito breeding sites or community surveys on household food insecurity during droughts. Communication and Leadership (C) • **Community awareness:** Deliver education sessions — e.g., how to keep drinking water safe during floods, or how to reduce indoor heat exposure. • **Risk communication:** Translate early warning alerts into actionable advice — e.g., "store drinking water before the cyclone," or "avoid outdoor work in peak heat hours." • **Dialogue facilitation:** E.g., Organize group discussions with farmers on climate impacts on nutrition, or with mothers on diarrheal disease prevention. • **Advocacy:** Report to local leaders - for e.g., if water supply contamination is causing recurring outbreaks. • **Collaboration:** E.g., work with disaster management teams, agriculture

(*continued on next page*)

Table 3 (*continued*)

Health workforce cadre and their functions identified in climate and health policies and/or HNAPs	Specific competencies and skills identified
	officers, and schools to set up community preparedness plans. • **Capacity building:** E.g., Mentor peer or volunteers to run household visits for mosquito net use, hygiene, or heat stress prevention. Practice (P) • **Early warning systems:** E.g., help maintain flood warning sirens and spread SMS/door-to-door alerts about upcoming heatwaves. • **Emergency preparedness**: Participate in mock drills for cyclones/floods, guiding families on evacuation routes and safe shelter practices. • **Surveillance role:** Promptly report unusual health patterns — e.g., a sudden rise in fever cases that may signal dengue outbreak. • **Screening & prevention:** Assist in screening camps for malnutrition after crop failure or checking for respiratory illnesses during wildfire season. • **Household engagement:** Demonstrate practical steps — e.g., boiling water, using oral rehydration during diarrhoea, improving ventilation in smoky kitchens. • **Service feedback:** Report if health centers lack essential medicines (like ORS, anti-malarials) during seasonal outbreaks. • **Resource stewardship in action:** Model sustainable practices — e.g., rational use of mosquito nets, community composting, or waste segregation during health campaigns.

when designing training and communication strategies. Tailoring messages to the channels preferred by different groups ensures guidance reaches everyone effectively, improves program implementation, and maximizes resource efficiency. For example, in a KAP survey in India, newspapers and television remain key sources for older or less formally trained health workers, while social media is more important for younger groups such as students and nurses. Public health professionals tend to rely extensively on their peer networks [5]. Understanding these patterns creates opportunities for targeted awareness campaigns and training delivery mechanisms. One approach that is especially relevant in resource-constrained settings is the 'train-the-trainer' model, where a few trained champions can cascade knowledge through peer networks or local meetings.

Training methods can also be adapted to the audience learning preferences - cadres relying on traditional media such as community health workers and administrators may benefit from storytelling, visuals, and practical exercises, whereas those with more formal learning exposure, like students and doctors, respond well to case studies, role plays, and academic readings that deepen engagement and enhance conceptual understanding.

Another consideration for policymakers is to first understand the specific training needs of the target learners before adopting any climate–health educational framework and developing a training program. Evidence shows that targeted interventions, even short courses, when designed with interactive and interdisciplinary methods, can effectively engage students and create interest in developing required skill set. For instance, medical students at the University of Oslo who completed a 2-week elective on climate change and health reported high satisfaction and motivation to continue learning, with growing interest in skills such as estimating the healthcare carbon footprint, implementing sustainable quality improvements, and adapting health services to climate-related challenges [26]. Broader surveys also indicate strong demand among healthcare students and professionals for structured climate–health education and training [29,30]. By conducting thorough needs assessments and identifying the learning priorities of different health cadres, especially in cases where they have previously received training, educators and policymakers can design and implement trainings that are relevant, engaging, and more likely to result in meaningful skill development.

4. Conclusions

This scoping review synthesized the existing evidence on the knowledge, attitudes, and skills required for health workers to manage climate-sensitive health risks and identified two recurring gaps: the limited availability of LMIC-specific frameworks and the lack of differentiation across workforce roles. Existing frameworks from high-income countries often prioritize formally trained professional groups and insufficiently reflect the broader range of health roles commonly found in under-resourced systems, including community health workers, mid-level practitioners, and other frontline cadres.

Ad hoc experiments with climate and health training modules and guidelines are reported in many LMIC settings, but these efforts have not been well documented or evaluated for efficacy [31–35]. A more systematic and coordinated approach is therefore needed, guided by public health goals and matched to the operational realities of LMICs. Deliberately moving away from a doctor-centric model toward a team-based approach can enhance workforce agility and adaptability, provided that the complementary skills and competencies of different cadres are clearly identified [36–38]. While all cadres require development across the five domains of capacity building defined here, the specific skill mix will vary according to the roles that clinical, public health, and community health workers play in different contexts.

Competency development also requires both formal and informal learning processes, including structured training and practical implementation. A continuous learning model is necessary to keep pace with evolving climate science, technologies, and policy landscapes. Evidence from the reviewed studies suggests that embedding periodic assessments, refresher modules, and micro-credentialing opportunities supports ongoing professional development and adaptability.

Overall, the framework and competency sets presented in this paper provide structured, context-appropriate guidance for strengthening the climate-resilience capabilities of the health workforce especially in LMICs. They offer a practical foundation for curriculum development, training design, and workforce planning aimed at improving preparedness and adaptive capacity within climate-vulnerable health systems.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used ChatGPT in order to identify some of the papers, and for editing tables. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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Declaration of competing interest

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