frontiers | Frontiers in Climate

TYPE Mini Review
PUBLISHED 28 May 2024
DOI 10.3389/fclim.2024.1304643

OPEN ACCESS

EDITED BY
Sherilee Harper,
University of Alberta, Canada

REVIEWED BY
John Barry,
Queen's University Belfast, United Kingdom
Alison Julia Katherine Green,
Scientists Warning Foundation, United States

*CORRESPONDENCE
Wajiha Qamar
✉ wajihaqamar.ob@gmail.com

†These authors have contributed equally to this work

RECEIVED 29 September 2023
ACCEPTED 15 May 2024
PUBLISHED 28 May 2024

CITATION
Qamar W, Qayum M, Nisa Wu, Khaleeq N and Ali A (2024) Promoting transdisciplinary collaboration in academia: uniting for climate-resilient health.
Front. Clim. 6:1304643.
doi: 10.3389/fclim.2024.1304643

Promoting transdisciplinary collaboration in academia: uniting for climate-resilient health

Wajiha Qamar[1]*, Mehran Qayum[2†], Waqar un Nisa[3†], Nadia Khaleeq[4†] and Asma Ali[1†]

[1]Department of Oral Biology, Bacha Khan College of Dentistry, Mardan, Pakistan, [2]Evidence for Health (E4H), Peshawar, Khyber Pakhtunkhwa, Pakistan, [3]Department of Oral Pathology, Bacha Khan College of Dentistry, Mardan, Pakistan, [4]Department of Community Dentistry, Institute of Public Health and Social Sciences, Khyber Medical University, Peshawar, Pakistan

In a world where some regions are directly experiencing the effects of the climate change, while others are more vulnerable; this article dives into the deep and frequently catastrophic impact of the climate change on vulnerable countries. This review emphasizes the need for transdisciplinary academic collaboration, including social scientists, healthcare professionals, engineers, policy experts, and climate scientists, and underscores academia's potential role in advancing climate-resilient health systems in these areas. The study promotes inclusive research that prioritizes at-risk groups, involves communities, and supports culturally sensible methodologies. Beyond their traditional tasks, academia has an obligation for action, learning, innovation, and change. To address the complex health concerns brought on by the planetary crisis, collaboration across academic fields and in tandem with communities, governments, and international organizations is crucial. Ongoing collaboration between academia, governments, and stakeholders is crucial to developing healthcare systems and technologies that are climate resilient. The complex role of academia involves developing pioneering solutions in healthcare for a sustainable future, advocating for policies based on evidence, and educating the next generation of professionals.

KEYWORDS

climate change, academia, faculty, intersectoral, vulnerable countries

Review

The need for transdisciplinary collaboration within academia is escalating as we strive toward climate-resilient health systems. The global health landscape is fragmenting more and more due to the impacts of climate change. This fragmentation is characterized by vulnerability, setting apart countries that have been significantly and directly affected by the global crisis from others (Abbass et al., 2022). For these vulnerable nations, the effects of climate change are not distant threats; rather, they are a daily part of life and frequently have dire consequences.

The effects of the planetary crisis are not an impending threat for these vulnerable countries; rather, they are integral parts of daily life and frequently have disastrous repercussions (Heshmati, 2020). The unwavering and escalating impacts of the planetary crisis have been clearly observed by the global health community, academia, and policy makers. Public health

in these vulnerable countries is disproportionately burdened by a complex web of health hazards that are made worse by socioeconomic inequality (Meier et al., 2022; Riaz et al., 2022). It is important to acknowledge that the problem encompasses not solely individual socioeconomic status but also broader socioeconomic disparities both within and between societies (Wilkinson and Pickett, 2009).

The need of resolving these inequities is highlighted by epidemiological research that links income and wealth disparities to unfavorable health outcomes, especially in vulnerable countries where the implications are most acute. Therefore, addressing and discussing these inequalities is imperative, particularly in vulnerable countries where the impact of such hazards are most noticeable (Wilkinson and Pickett, 2009).

This review intends to explore how transdisciplinary collaboration in academia can foster the development of a climate-resilient health systems in vulnerable countries, emphasizing the urgent need for such initiatives.

Advancing climate-resilient health systems and policy changes

Advancing climate-resilient health systems and policy changes involves developing healthcare systems that can anticipate, withstand, and adapt to the adverse impacts of climate change on human health. This entails putting plans in place to enhance community engagement, response capabilities, and healthcare infrastructure—all with the aim of providing sustainable and effective health services. Academic institutions can play a crucial role by serving as epicenter for learning, innovation, and change. Amidst a global existential crisis that affects millions of people's health and lives, academia plays a more significant role than traditional teaching and research in promoting policy reforms and practical improvements, particularly in vulnerable countries.

Reports like the Lancet Countdown on Health and Climate Change and the Intergovernmental Panel on Climate Change (IPCC), particularly the Special Report on Global Warming of 1.5°C, provide a robust, data-driven synthesis of research highlighting the relationship between health vulnerabilities and the global crisis (Watts et al., 2018). Such analyses highlight the numerous health risks linked to climate change and the pressing need for policy interventions.

This evidence-based shift in perspective has had a major impact on national and international policy discussions, highlighting the necessity of incorporating health imperatives into more comprehensive frameworks for climate adaptation. Policymakers may create more comprehensive and effective plans to reduce the impact of climate change on public health through making health concerns priority. In the wake of the global existential crisis, academia is leading the effort to advance practical improvements and policy reforms in vulnerable countries. One crucial strategy for turning evidence into action and advancing the development of climate-resilient health systems and policy changes is to foster transdisciplinary partnerships.

Fostering transdisciplinary partnerships

Promoting transdisciplinary collaboration is essential as academia seeks to address the many issues surrounding the planetary crisis (Bruin and Morgan, 2019). This is because it demands the expertise of social scientists, medical professionals, engineers, policy experts, and climate scientists (Getson et al., 2020). In the context of health, interdisciplinary and transdisciplinary collaboration is particularly important for several reasons. The health issues associated with the climate change are inherently complicated and intertwined, necessitating knowledge from a variety of fields in order to formulate feasible solutions. For example, epidemiologists, climatologists, biologists, and public health specialists contribute to our understanding of how vector-borne illnesses spread as a result of changing climatic circumstances. To effectively manage this complexity, academia should encourage transdisciplinary collaboration and engage in action-oriented research to encourage academics to collaborate across disciplines, encouraging cross-disciplinary research and initiatives. This is because new ideas often emerge from the intersection of multiple fields of knowledge (Buse et al., 2022). It is imperative that measures be taken now, and academia adopt a proactive strategy that addresses the underlying causes of global issues rather than being a passive observer. This entails developing an engaged research culture that motivates academia to actively cooperate, develop, and implement useful solutions into implementation. It is important for several reasons to support early-career researchers, including graduate students and postdoctoral associates, in participating in multidisciplinary discussions. First, advances in technology need a synthesis of information from many fields, such as the integration of ecological knowledge and genomics for biological research pertaining to the planetary crisis. Second, the advancement of the climate change research is greatly influenced by these experts, and the early adoption of multidisciplinary methodologies can influence future practices (Gornish et al., 2013). Finally, because the planetary crisis is a worldwide issue, encouraging international cooperation among these experts provides a wider, more global viewpoint that is advantageous for this kind of study (Gornish et al., 2013). However, the bibliometric analysis and of early to mid-career scientists from 56 countries who were involved with the interdisciplinary DISsertations initiative for the advancement of Climate Change ReSearch (DISCCRS) shows, early career researchers face a number of obstacles, including conflicts related to career advancement (Hein et al., 2018). Nevertheless, interventions such as networking and training symposia have a positive impact on engagement, underscoring the significance of funding interdisciplinary grants, training, and integrating interdisciplinarity into tenure evaluations to overcome structural barriers and promote its growth (Hein et al., 2018).

Multiple studies emphasizes the significant impact of historical actions on climate interventions and requires for a nuanced pedagogy that takes lived experiences and trauma informed approaches (Graham et al., 2023a; Houghton et al., 2023). It also highlights the necessity of implementing a cutting-edge transdisciplinary approach to steer research in integrating multiple perspectives on the evolution of transitions in interconnected social-environmental systems, with a particular focus on the insightful information provided by the idea of tipping points in influencing important social-environmental transitions (Houghton et al., 2023). Aiming for comprehensive transformation in academia for the development of climate-resilient health systems entails going beyond discrete pedagogical methodologies, both inside and outside the institution's boundaries. This calls for adopting a variety of knowledge systems and broadening,

cross-sectoral viewpoints, which calls for working with stakeholders—including local communities—in a variety of ways (Fadeeva et al., 2018; Cordero et al., 2020). Through collaboration between engineering and healthcare professionals, the health implications of the planetary crisis in vulnerable regions were greatly minimized by technical solutions appropriate for local circumstances (Vourdoubas, 2021). Universities can also develop incentives for this kind of cooperation by recognizing academics and researchers who work on multidisciplinary initiatives. A variety of notable gaps have been found in the formulation of the climate change policies, such as the lack of research centers, lack of existence of dedicated courses on the planetary crisis, the lack of specialized lecturers, the long-term funding needs for climate research, and the requirement for sophisticated mathematical modeling skills (Mardiastuti, 2020). The importance of transdisciplinary Climate Change Committees (CCCs) for enhancing climate governance policies and strategies cannot be overlooked (Abraham-Dukuma et al., 2020). These CCCs are made up of experts from a variety of fields and are tasked with advising governments or organizations on climate policy and strategy. This ensures their authority, democratic legitimacy, and usefulness in improving climate governance policies and strategies. A study, emphasizes how, although not ensuring immediate gains in a country's climate performance, these committees, with their many areas of expertise, are essential in addressing climate challenges and promoting long-term climate goals (Abraham-Dukuma et al., 2020). Academics should seek resources through partnerships with organizations, private foundations, and governmental organizations that support multidisciplinary climate research, with the goal of building capacity as a cornerstone of their commitment to transdisciplinary climate research. They should be cautious when forming alliances with business entities, particularly those that might generate conflicts of interest, to have academic independence and research integrity through open policies and oversight.

Targeted research projects

Transdisciplinary research can assist in providing a framework for developing policies that better align climate funding with the intricacies of how the planetary crisis affects infrastructure, society, and health (Weaver and Miller, 2019; Graham et al., 2023b) and for monitoring and evaluating climate financing. These frameworks are necessary for tracking the effectiveness and efficiency of investments (König et al., 2013). By utilizing knowledge from the social sciences, engineering, policy analysis, and healthcare, multidisciplinary research may provide strong guidelines and benchmarks to assess project results, ensuring efficient utilization of funds (Song et al., 2023). Increasing involvement beyond traditional experts through approaches like "post-normal science" and "citizen science" is essential in action-oriented climate and multidisciplinary research. These approaches democratize scientific process research by facilitating greater participation and a range of viewpoints. Academics can enhance the significance and influence of research efforts in addressing urgent global issues like climate change by adopting these inclusive approaches that highlight the need to consider vulnerable populations in research on climate resilience (UNESCO, 2017). These vulnerable communities, frequently situated in areas with inadequate resources, social injustices, and inadequate infrastructure, suffer the most from the impacts of the planetary crisis. The research projects should begin with inclusive vulnerability assessments that actively engage these populations by taking into consideration socioeconomic inequalities, cultural settings, and geographic variables (Taylor et al., 2022). Research should focus on cocreating adaptive solutions with these communities as it advances to ensure that interventions are both contextually and culturally appropriate. The strategy may entail information exchange, equitable resource distribution, and community-based adaptation approaches, all of which would be backed by a commitment to ongoing community engagement. Academia's role in this context entails encouraging multidisciplinary research, fostering communication between researchers and communities in need, and advocating for targeted climate funding (Reimers, 2021). This approach will assist in bridging gaps in climate resilience and fostering a more sustainable future for everyone.

Understanding the complex relationships between the climate change and its impact on health outcomes is crucial for several reasons. It begins with monitoring and assessing the evolving landscape of health hazards because of the planetary crisis, including vector-borne illnesses, the psychological and mental health consequences of severe weather, and the impact of deteriorating air quality on respiratory health (Wu et al., 2016; Fox et al., 2019). Furthermore, academia can play a crucial role in formulating and assessing adaptation plans intended to safeguard public health from the effects of the planetary crisis. Study conducted by Sahana, assessed the effectiveness of early warning systems and their impact on community resilience to climate-induced health risks and demonstrated that coastal communities were more vulnerable due to a lack of early warning awareness and delays in emergency preparedness, underscoring the urgent need for policy interventions to reduce cyclone-related economic losses in the Sundarban Biosphere Reserve (SBR) (Sahana et al., 2023). The primary objective of this research is to comprehend how these actions improve community resilience while reducing health risks. Academic research should carefully assess the results of the mitigation measures for climate-related health concerns, including vaccination campaigns adjusted to shifting disease patterns, urban planning techniques in controlling heatwaves, and effects of disaster preparedness initiatives. Policymakers and healthcare professionals can leverage evidence-based decisions from such studies to make informed decisions.

Strategies for resilience and policy action

Academia could actively encourage the development and enactment of policies emphasizing the need to take preventative measures to address the health risks brought on by the planetary crisis (Reimers, 2021). These policies acknowledge that the planetary crisis poses a serious threat to human health that goes beyond environmental issues. Empirical evidence and analytical insights from academic research support the necessity of integrating public health safeguards with efforts for climate adaptation (Fox et al., 2019; Reimers, 2021). The majority of research focused on the way experts helped policy makers shape policies through mutual learning. They emphasize how policymaking is impacted by the involvement of multiple specialists,

a variety of stakeholders, and communicating complex information affects policymaking (Wagner et al., 2023).

The academic community can significantly contribute to developing integrated health-climate policy that prioritizes preventative measures to address the health risks brought on by the planetary crisis (Stordalen et al., 2013; Reimers, 2020; Pillai et al., 2021). These policies acknowledge the significant hazards that the planetary crisis poses to people's health, threats that go beyond environmental considerations. The role of academia in developing evidence-based policy recommendations will become increasingly more crucial as the impacts of the planetary crisis worsen (Reimers, 2020). This responsibility also includes locating particularly vulnerable populations and developing specific interventions. To ensure that climate adaptation and health protection are integrated into policymaking and support the successful implementation of integrated policies, academic institutions will also use their influence when interacting with policymakers, international organizations, and public health organizations.

Academic institutions play a vital role in training communities, public health workers, and healthcare professionals to successfully address climate-related health concerns. This function complements lobbying for integrated health-climate policy in a harmonic way. To bridge this knowledge gap, academic institutions must actively encourage knowledge through the development of curricula, transdisciplinary cooperation, research funding, ongoing education, and international cooperation. According to the study, teachers who took part in the professional development workshops had a greater understanding of the planetary crisis, which raised educators' awareness of the issue (Dal et al., 2015). Efforts are made to include studies to ensure that students from different academic fields have a clear understanding of how the planetary crisis affects health (Shaman and Knowlton, 2018; Cerceo et al., 2022; Ramadani et al., 2023). This integration includes academic disciplines, including engineering, social sciences, and policy studies, in addition to conventional medical and public health programs. To foster research and educational initiatives, transdisciplinary interaction is actively encouraged within academia. Governments and private organizations are being encouraged to commit resources for research on the climate change and health to further advance understanding in this crucial field. Such financing can assist educational institutions in carrying out important research, providing instructional materials, and offering specialized courses. Grants and scholarships may encourage students to pursue careers in this critical field. In addition to doing research, academics are increasingly cognizant of the significance of actively supporting the combination of climate adaptation and health protection on a worldwide basis (Shaman and Knowlton, 2018; Cerceo et al., 2022). Academic institutions can forge partnerships with governments, nongovernmental organizations, and international bodies to facilitate information exchange, collaborative research, and joint initiatives. By providing governments and international organizations with recommendations based on solid research, academic institutions may persuade them to give climate-resilient healthcare programs top priority. In the future, academia is anticipated to assume a greater role in global advocacy and cooperation (Gardner et al., 2021). This expanded role includes identifying vulnerable populations, developing targeted interventions, and actively advocating for the inclusion of health protection and climate adaptation in policies (Gardner et al., 2021).

Academic projects in climate-resilient healthcare innovation and implementation

Academia plays a crucial role in preparing the healthcare staff to navigate the challenges arising from the planetary crisis by developing capacity building programs (Fadeeva et al., 2018). These programs, integrating knowledge from the diverse fields, have to be developed to produce a workforce prepared to address health-related issues brought on by the planetary crisis.

Academica can spearhead in establishing preventative measures through research aimed at identifying vulnerabilities and adopting evidence-based strategies to mitigate the health hazards associated with the planetary crisis. The effectiveness of these strategies could be enhanced by adaptation of these strategies to specific regions, taking socioeconomic and cultural contexts into consideration (Dal et al., 2015). Academics might also take part in emergency response and preparedness activities, developing policies and guidelines to strengthen healthcare systems' ability to withstand climate-related catastrophes. This proactive engagement will ensure a robust and flexible response to the constantly evolving issues brought forth by the planetary crisis. Additionally, by undertaking research that deepens our understanding of the complex interactions between the planetary crisis and health consequences, academia plays a crucial role in closing knowledge gaps (Urai and Kelly, 2023).

Since academia plays a critical role in educating healthcare professionals and spearheading initiatives to address the planetary crisis, its seamless transition to academic settings is evident. Acknowledging the need for novel approaches, these institutions could proactively participate in cutting-edge research and aid in the creation of climate-resilient healthcare solutions, so reinforcing their position in the shift toward sustainable and adaptable healthcare systems.

The science-society contract is strained, emphasizing the critical importance of redirecting efforts and showing sincere dedication to fulfilling responsibilities while promptly coordinating action across local and global scales (Glavovic et al., 2022). Fostering diversity and transparency within the scientific community becomes essential as recognition underlines the necessity for a concentrated effort to close the gap between scientific results and society response. This acknowledgement emphasizes how important it is for scientists to actively interact with a variety of groups and stakeholders to ensure sure that scientific research is both relevant to and accessible to a wider audience. It is imperative that social scientists who are dedicated to the idea of public engagement evaluate the approach and provide more in-depth explanations and analyses. Scientists ought to support the idea of "publicly engaged science," which encompasses a more comprehensive framework and an ambitious approach to integrating public ideas and values into scientific endeavors, rather than focusing just on promoting public engagement.

To address pressing global challenges, academics should also actively participate in political mobilization and public education campaigns in addition to expanding their impact outside of the boundaries of their research. For example, immediate attention and action are required to address the detrimental consequences of fossil

fuels on public health. Academia could radically alter society attitudes and policies, increase public awareness, and influence public opinion on these important topics since they have the information, experience, and power to do so. By making use of their platforms and areas of expertise, academics may promote futures that are healthier, more equitable, and sustainable for all. This increased involvement highlights the increased societal responsibility and impact of academics. By means of joint efforts and cooperation with diverse stakeholders, such as legislators, community organizations, and the wider public, scholars may make a significant contribution to transformative changes in society and tackle the pressing environmental and public health issues confronting our planet.

A greater emphasis on transdisciplinary research in the context of academia and climate change may lead to innovative concepts that go beyond the boundaries of current research. Transdisciplinary approaches foster innovation and creativity in addressing climate-related concerns by incorporating viewpoints from other sectors, such as science, technology, engineering, social sciences, and humanities. Transdisciplinary research, for example, may result in the development of novel technology for the development of renewable energy, sustainable agricultural methods, or climate change-resilient urban planning concepts. Academic institutions are cognizant of the challenges brought on by the climate change, such as the escalating frequency of extreme weather events, shifting illness trends, and infrastructural disruptions in the healthcare industry (Reimers, 2021). These challenges demand innovative solutions that can adapt to changing environmental conditions while ensuring the continuity of healthcare services. However, academia has its own set of challenges, the need for transdisciplinary research collaboration among scholars from different sectors and the efficient transfer of research discoveries into practical applications (Gibson et al., 2019). Academic institutions are currently actively involved in cutting-edge studies designed to promote innovation in healthcare technology and practice (Stefanis et al., 2022). They aim to enhance disaster preparedness and response plans, create new medical technology that is appropriate for extreme conditions, and encourage the use of digital health solutions (Stefanis et al., 2022). Academic research provides the information and insights required to guide novel approaches to healthcare that are climate-resilient, serving as the foundation for these creative endeavors. In the future, academics will play a more significant role in healthcare innovation as the impacts of global warming worsen (Matos et al., 2022). Academic institutions will continue taking the lead in creating cutting-edge healthcare practices and technology that improve climate resilience. Additionally, they will be essential in ensuring that these technologies are applied in actual healthcare settings. To do this, corporations, healthcare providers, and legislators need to collaborate to transform research-driven discoveries into workable community-benefiting solutions.

Effective monitoring, evaluation of interventions, policies, and capacity-building initiatives are central to academia's multifaceted role in fostering climate-resilient health systems. Effectiveness has been shown in initiatives meant to increase the public's awareness of the planetary crisis and sustainable development (Mebane et al., 2023). They significantly raised students' awareness of environmental issues, enhanced their comprehension of the emotions associated with the planetary crisis, and encouraged the development of climate-related initiatives (Mebane et al., 2023). It is crucial to overcome the challenges with gathering information, processing, and interpretation to evaluate the intricate relationships between the planetary crisis and its impact on health. Understanding the complex relationships between the climate change and health outcomes necessitates close attention to detail, the development of complex processes, and the collection of a wide range of information. Evaluation efforts must consider both short- and long-term consequences, as well as the nuances of how the planetary crisis affects health. Continuous monitoring and assessment activities are essential given the challenging nature of this task.

In conclusion, academia appears to be an essential player in the development of health systems that are climate resilient in vulnerable countries, through its ability to generate knowledge, innovate solutions, and influence policy. Academia can take the lead in tackling the complex problems posed by the planetary crisis to public health through multidisciplinary cooperation, inclusive research practices, global advocacy, capacity building, and innovation. The importance of academics will only grow as we look to the future, necessitating more collaboration with governmental bodies, global organizations, and healthcare stakeholders. To create a more climate-resilient and sustainable future for everyone, it is crucial that academia to actively engage in the development of evidence-based policies, cutting-edge healthcare solutions, and monitoring and evaluation initiatives.

Author contributions

WQ: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Conceptualization. MQ: Writing – review & editing, Writing – original draft, Software, Resources, Methodology. WN: Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Formal analysis. NK: Writing – review & editing, Software, Methodology, Formal analysis. AA: Writing – review & editing, Software.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

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

Publisher's note

References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., and Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environ. Sci. Pollut. Res.* 29, 42539–42559. doi: 10.1007/s11356-022-19718-6

Abraham-Dukuma, M. C., Dioha, M. O., Bogado, N., Butu, H. M., Okpaleke, F. N., et al. (2020). Multidisciplinary composition of climate change commissions: transnational trends and expert perspectives. *Sustain. For.* 12, 1–23. doi: 10.3390/su122410280

Bruin, W. B., and Morgan, M. G. (2019). Reflections on an interdisciplinary collaboration to inform public understanding of climate change, mitigation, and impacts. *Environ. Sci.* 116, 7676–7683. doi: 10.1073/pnas.1803726115

Buse, K., Tomson, G., Kuruvilla, S., Mahmood, J., Alden, A., Mvd, M., et al. (2022). Tackling the politics of intersectoral action for the health of people and planet. *BMJ*:376. doi: 10.1136/bmj-2021-068124

Cerceo, E., Saberi, P., and Becker, J. (2022). Interactive curriculum to teach medical students health and climate change. *J. Clim. Change Health.* 5:100105. doi: 10.1016/j.joclim.2021.100105

Cordero, E. C., Centeno, D., and Todd, A. M. (2020). The role of climate change education on individual lifetime carbon emissions. *PLoS One* 15:e0206266. doi: 10.1371/journal.pone.0206266

Dal, B., Ozturk, N., Alper, U., Sonmez, D., and Cokelez, A. (2015). An analysis of the teachers' climate change awareness. *Athens J. Educ.* 2, 111–122. doi: 10.30958/aje.2-2-2

Fadeeva, Z., Galkute, L., and Chhokar, K. (2018). *Academia and communities: Engaging for change*. United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS): The United Nations University.

Fox, M., Zuidema, C., Bauman, B., Burke, T., and Sheehan, M. (2019). Integrating public health into climate change policy and planning: state of practice update. *Int. J. Environ. Res. Public Health* 16, 1–22. doi: 10.3390/ijerph16183232

Gardner, C. J., Thierry, A., Rowlandson, W., and Steinberger, J. K. (2021). From publications to public actions: the role of universities in facilitating academic advocacy and activism in the climate and ecological emergency. *Front. Sustain.* 2:2. doi: 10.3389/frsus.2021.679019

Getson, J. M., Sjöstrand, A. E., Church, S. P., Weiner, R., Hatfield, J. L., and Prokopy, L. S. (2020). Do scientists have a responsibility to provide climate change expertise to mitigation and adaptation strategies? Perspectives from climate professionals. *Public Underst. Sci.* 30, 169–178. doi: 10.1177/0963662520966690

Gibson, C., Stutchbury, T., Ikutegbe, V., and Michielin, N. (2019). Challenge-led interdisciplinary research in practice: program design, early career research, and a dialogic approach to building unlikely collaborations. *Res. Eval.* 28, 51–62. doi: 10.1093/reseval/rvy039

Glavovic, B. C., Smith, T. F., and White, I. (2022). The tragedy of climate change science. *Clim. Dev.* 14, 829–833. doi: 10.1080/17565529.2021.2008855

Gornish, E. S., Hamilton, J. A., Barberán, A., Benito, B. M., Binzer, A., DeMeester, J. E., et al. (2013). Interdisciplinary climate change collaborations are essential for early-career scientists. *Trans. Am. Geophys. Union* 94:151. doi: 10.1002/2013EO160003

Graham, S., Wary, M., Calcagni, F., Cisneros, M., Luca, C., Gorostiza, S., et al. (2023a). An interdisciplinary framework for navigating social–climatic tipping points. *People Nat.* 5, 1445–1456. doi: 10.1002/pan3.10516

Graham, S., Wary, M., Calcagni, F., Cisneros, M., Luca, C., Gorostiza, S., et al. (2023b). An interdisciplinary framework for navigating social–climatic tipping points. *People Nat.*, 1–12,

Hein, C. J., Hoeve, J. E. T., Gopalakrishnan, S., Livneh, B., Adams, H. D., Marino, E. K., et al. (2018). Overcoming early career barriers to interdisciplinary climate change research. WIREs. *Climate Change* 9:e530. doi: 10.1002/wcc.530

Heshmati, HM. Environmental issues and sustainable development (2020). Available at: https://www.intechopen.com/books/9664

Houghton, S., Garvey, J., Conor, L., Wilmsen, B., Dehm, J., Gamble, R., et al. (2023). Towards an interdisciplinary agenda for teaching in the climate crisis: reflections from the humanities and social sciences. *Environ. Educ. Res.*, 1–13. doi: 10.1080/13504622.2023.2273791

König, B., Diehl, K., Tscherning, K., and Helming, K. (2013). A framework for structuring interdisciplinary research management. *Res. Policy* 42, 261–272. doi: 10.1016/j.respol.2012.05.006

Mardiastuti, A. (2020). Gaps in science and policy formulation of climate change: perspective from university. *IOP Conf. Ser. Earth Environ. Sci.* 487:012003. doi: 10.1088/1755-1315/487/1/012003

Matos, S., Viardot, E., Sovacool, B. K., Geels, F. W., and Xiong, Y. (2022). Innovation and climate change: a review and introduction to the special issue. *Technovation*:117. doi: 10.1016/j.technovation.2022.102612

Mebane, M. E., Benedetti, M., Barni, D., and Francescato, D. (2023). Promoting climate change awareness with high school students for a sustainable community. *Sustain. For.* 15:11260. doi: 10.3390/su151411260

Meier, B. M., Bustreo, F., and Gostin, L. O. (2022). Climate change, public health and human rights. *Int. J. Environ. Res. Public Health* 19:13744. doi: 10.3390/ijerph192113744

Pillai, P., Patz, J. A., and Seibert, C. S. (2021). Climate change and environmental health must be integrated into medical education. *Acad. Med.* 96, 1501–1502. doi: 10.1097/ACM.0000000000004238

Ramadani, L., Khanal, S., and Boeckmann, M. (2023). Climate change and health in school-based education: a scoping review protocol. *PLoS One* 18:e0282431. doi: 10.1371/journal.pone.0282431

Reimers, F. M. (2020). *Education and climate change*. Cham: Springer.

Reimers, F. M. (2021). The role of universities building an ecosystem of climate change education. *Educ. Clim. Change*, 1–44. doi: 10.1007/978-3-030-57927-2_1

Riaz, K., Ahmad, M., Gul, S., and Malik, M. H. B. A. (2022). Rehman MEU. Climate change and its implications on health and the healthcare system: a perspective from Pakistan. *Ann. Med. Surg.*:81,

Sahana, M., Patel, P. P., Rehman, S., Rahaman, M. H., Masroor, M., Imdad, K., et al. (2023). Assessing the effectiveness of existing early warning systems and emergency preparedness towards reducing cyclone-induced losses in the Sundarban biosphere region, India. *Int. J. Disast. Risk Reduc.*:90. doi: 10.1016/j.ijdrr.2023.103645

Shaman, J., and Knowlton, K. (2018). The need for climate and health education. *Am. J. Public Health* 108, S66–S67. doi: 10.2105/AJPH.2017.304045

Song, Y., Fang, Z., and Fu, H.-Z. (2023). Influence of interdisciplinarity on scientific impact: the case of climate change field. *J. Informet.* 17:101410. doi: 10.1016/j.joi.2023.101410

Stefanis, C., Giorgi, E., Kalentzis, K., Tselemponis, A., Tsigalou, C., Nena, E., et al. (2022). Assessing worldwide research activity on ICT in climate change using Scopus database: a bibliometric analysis. *Front. Environ. Sci.* 10:10. doi: 10.3389/fenvs.2022.868197

Stordalen, G. A., Rocklöv, J., Nilsson, M., and Byass, P. (2013). Only an integrated approach across academia, enterprise, governments, and global agencies can tackle the public health impact of climate change. *Glob. Health Action* 6:20513. doi: 10.3402/gha.v6i0.20513

Taylor, M., Eriksen, S., Vincent, K., Brooks, N., Scoville-Simonds, M., and Schipper, E. L. F. (2022). *Putting 'vulnerable groups' at the Centre of adaptation interventions by promoting transformative adaptation as a learning process*. Norway: Norwegian University of Life Science's.

UNESCO (2017). Declaration of Ethical Principles in relation to Climate Change 2017 Available at: https://en.unesco.org/about-us/legal-affairs/declaration-ethical-principles-relation-climate-change

Urai, A. E., and Kelly, C. (2023). Rethinking academia in a time of climate crisis. *eLife* 12:12. doi: 10.7554/eLife.84991

Vourdoubas, J. (2021). Use of renewable energy sources for heat and cooling generation in hospitals. *Am. Acad. Sci. Res. J. Eng. Technol. Sci.* 1, 98–112. doi: 10.24018/ejgeo.2020.1.6.88

Wagner, N., Velander, S., Biber-Freudenberger, L., and Dietz, T. (2023). Effectiveness factors and impacts on policymaking of science-policy interfaces in the environmental sustainability context. *Environ. Sci. Pol.* 140, 56–67. doi: 10.1016/j.envsci.2022.11.008

Watts, N., Amann, M., Arnell, P. N., Ayeb-Karlsson, S., Belesova, K., Berry, P. H., et al. (2018). The 2018 report of the lancet countdown on health and climate change: shaping the health of nations for centuries to come. *Lancet* 392, 2479–2514. doi: 10.1016/S0140-6736(18)32594-7

Weaver, C. P., and Miller, C. A. (2019). A framework for climate change-related research to inform environmental protection. *Environ. Manag.* 64, 245–257. doi: 10.1007/s00267-019-01189-0

Wilkinson, R. D., and Pickett, K. (2009). *The spirit level: Why more equal societies almost always do better*. Allen Lane/Penguin Group UK: Bloomsbury Publishing.

Wu, X., Lu, Y., Zhou, S., Chen, L., and Xu, B. (2016). Impact of climate change on human infectious diseases: empirical evidence and human adaptation. *Environ. Int.* 86, 14–23. doi: 10.1016/j.envint.2015.09.007