

Perspectives and Debates

Teaching about climate change in medical education: an opportunity

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Significance for public health

There is a strong case for teaching about climate change in medical education. Anthropogenic climate change is accepted by scientists, governments and health authorities internationally. Given the dire implications for human health, climate change is of fundamental relevance to future doctors. Integrating climate change into medical education offers an opportunity for future doctors to develop skills and insights essential for clinical practice and a public health role in a climate-changing world. This echoes a broader call for improved public health literacy among medical graduates. This paper provides medical schools with a rationale and an outline for teaching on climate change.

Abstract

Climate change threatens many of the gains in development and health over the last century. However, it could also be a catalyst for a necessary societal transformation to a sustainable and healthy future. Doctors have a crucial role in climate change mitigation and health system adaptation to prepare for emergent health threats and a carbon-constrained future. This paper argues that climate change should be integrated into medical education for three reasons: first, to prepare students for clinical practice in a climate-changing world; secondly, to promote public health and eco-health literacy; and finally, to deepen existing learning and strengthen graduate attributes. This paper builds on existing literature and the authors' experience to outline potential learning objectives, teaching methods and assessment tasks. In the wake of recent progress at the United Nations climate change conference, COP-21, it is hoped that this paper will assist universities to integrate teaching about climate change into medical education.

Introduction

Climate change has the potential to dwarf existing health concerns, undermine development achievements, and pose significant adaptation and mitigation challenges.¹⁻⁶ But climate change also presents societies and medical educators with an opportunity to consider the assumptions and paradigms that underpin persisting challenges in health, equity and sustainability.⁷ This paper argues that doctors have a fundamental role in supporting a necessary social transition that addresses these challenges. Informed by existing literature and teaching experience, the authors suggest learning objectives, teaching methods and assessments that integrate the nuances of curriculum design and reflect the need for deep learning of concepts, knowledge and skills in order to respond to climate challenges.⁸⁻¹⁴

Climate change and health

Climate change endangers human health through destabilising the ecological and social systems that provide core human needs.³ In the context of the Anthropocene, a time when humans are the dominant influence on the planet,¹⁵ Steffen *et al.* describe nine *planetary boundaries* which define a *safe operating space for humanity*.¹⁶ Importantly, these boundaries do not define tipping points in the planetary system, but mark a zone of increasing uncertainty around risk. Climate change is one domain which has transgressed the planetary boundary into increasing risk and uncertainty. Like alterations to the biosphere, climate change is of particular concern as it risks a sudden major change in the earth's environment which could be catastrophic.^{16,17}

Climate change affects health in a myriad of ways.^{1,5,18} Risks can be categorised as *immediate and direct risks*, *indirect risks*, *deferred and diffuse risks*, and *risks associated with conflict and refugee flows*.³ *Immediate and direct risks* include heatwaves, extreme weather events and altered air quality.³ The increasing intensity and frequency of extremes have the potential to overwhelm adaptive capacity and cause considerable premature mortality, as was evident in the 2010 Pakistani flood and 2003 European heatwave. *Indirect risks* to health occur through changes to ecosystems and biophysical systems, affecting infectious disease distribution, crop yields, fish stocks, aeroallergens, water quality and flows, and bacterial growth rates.³ Ultimately, climatic shifts cause stress and disrupt livelihoods, leading to *deferred and diffuse risks* to mental and physical health. For mental health: extreme events can cause stress and trauma; and existential concerns about humanity and the planet can cause anxiety and depression.¹⁹ Climate change poses further risks to health through increases in *civil conflict and social instability* and forced migration,²⁰⁻²² potentially dwarfing existing refugee crises.

Health impacts can be considered *climate-sensitive* or *climate-induced*. *Climate-sensitive* illnesses encompass exacerbations in respiratory, cardiovascular and renal disease, which may be triggered by heat waves or air pollution. *Climate-induced* illnesses encompass infectious disease, malnutrition, heat stroke, and mental illness.

Climate change and health inequity are inextricable. As a *risk-amplifier*, climate change exacerbates existing inequities and vulnerabilities.^{11,23-25} Populations with a low *adaptive capacity* are frequently more *climate-sensitive*, for example, low and middle income countries have larger subsistence farming populations whose livelihoods are more vulnerable to environmental changes. These regions are predicted to experience greater *exposure* to climate change despite comparatively small historical greenhouse emissions.²⁶ Climate change represents a classic global health issue; it is characterised by inequity in exposure, contribution, vulnerability and capacity to respond.

To achieve health equity, and indeed broader societal equity, climate change, and ecological sustainability, must be core focuses. Conversely, to legitimately achieve and maintain a *safe operating space for humanity* that avoids catastrophic climate change requires resolution of global inequities.¹⁶ Sustainability can be considered a primary criterion for health equity; and health equity a primary criterion for

sustainability,²⁷ an approach reflected in the Sustainable Development Goals. To ameliorate these climate health risks, the health sector has a crucial role in highlighting the interconnectedness of sustainability and health, and advocating for policies that reflect this foundation.

Beyond advocating for a broader eco-health lens, the health sector has diverse roles in mitigation and adaptation. Comprehensive health sector adaptation plans need to be inter-sectoral and transdisciplinary. Synergies between health challenges and climate challenges need to be sought. For instance, food systems can be developed that address the triple burden of malnutrition, and promote sustainability and climate change mitigation.²⁸ Health adaptation needs to encompass: epidemiological surveillance and planning of regional and global climate risks; governance and institutional planning; community health promotion and emergency preparedness; workforce development and education; and strategic finance and investment.⁸

Improved health service sustainability has a strong public health rationale,⁸ reinforced by environmental and economic necessities.¹ Health services require vast resources and have significant greenhouse emissions.²⁹ They can be considered *carbon-exposed*. This means that in a carbon-constrained society committed to lower greenhouse emissions scenarios, health services may encounter escalating financial,³⁰ feasibility and ethical concerns.^{31,32} Finally, unmitigated climate change is associated with high economic cost which endangers the viability of current health service models.^{31,32} Health services are increasingly recognising these constraints; for example, the UK health sector, which contributes 25% of public sector greenhouse emissions,³³ has committed to a reduction of at least 34% in greenhouse emissions by 2020.³⁴

Many mitigation strategies have independent positive impacts on health, the environment and society beyond mitigation of climate-related risk; these are termed *co-benefits*.^{1,17,35-37} Through this lens, the overall cost of mitigation strategies is reduced and some strategies have a net economic benefit.¹ Reductions in outdoor air pollution from fossil fuel use in transport and electricity production can achieve dramatic reductions in respiratory disease and premature deaths,³⁶ largely due to reductions in sulphur dioxide, nitrous oxide and particulate matter.³⁸ Likewise, non-fossil-fuel-based cooking stoves in low-income countries can reduce morbidity associated with indoor air pollution. Active transport and public transport can reduce traffic accidents,³⁸ rates of obesity, diabetes, cancer and cardiovascular disease.³⁷ Nutritionally appropriate reduction in meat consumption can reduce cardiovascular disease and some cancers.³

The links between climate change and health present a compelling argument for medical education to prepare doctors for health sector mitigation and adaptation to climate change.^{10,11,38-42} However, it is not possible to prescribe a single climate change curriculum that will have international applicability. Climate change health impacts will be influenced by pre-existing health status and social conditions, as well as exposure, adaptive capacity and sensitivity to climate change. An added complexity is the uncertainty around regionally specific and disease specific climate change risks.¹³ Although some risks exhibit clear international trends, such as an increase in frequency and intensity of heatwaves, other risks, such as the distribution of infectious disease, are less predictable.^{8,42} A climate change curriculum therefore needs to evolve with emerging evidence and local needs. Yet there are certain concepts and skills that could be considered core learning objectives.

Climate change curriculum

This paper proposes three inter-related reasons for medical students to learn about climate change (Figure 1). First, doctors need to be able to manage climate-related illness, engage in local health promotion

and prevention, and provide healthcare in a responsible and sustainable way. Secondly, teaching about climate change offers an avenue to improve public health literacy and eco-health literacy, which are essential to building a climate-resilient society and health-sector. Thirdly, climate change can be used to illustrate and deepen existing learning, and strengthen graduate attributes.

Clinical climate change preparedness

Studies indicate that medical students and doctors are aware of the health effects of climate change but feel unprepared for health sector mitigation and adaptation.⁴³⁻⁴⁷ Doctors need to be familiar with regional climate health risks to individuals and communities to develop competence in clinical practice.^{5,9,25,47} These competencies are explored in detail in Table 1.^{11,13,14,31,32,48-51} Broadly, doctors need clinical expertise to identify vulnerable patients,⁵² address risk factors,⁴¹ and diagnose and manage climate-related physical and mental illness.^{13,32} Climate change is expected to shift the distribution and intensity of health needs, increasing demand for baseline and emergency services.¹¹ Increasing pressures may require doctors other than those in public health and emergency disciplines to engage in epidemiology, emergency response and community education.^{9,11,41}

Regional differences in climate change and communities will create diverse demands on doctors.³² For example, in Australia, rural practitioners may need to be cognisant of mental illness during drought and engage in health promotion and screening, or contribute to emergency planning for heatwaves, bushfires or floods. Doctors in urban areas may need to promote awareness of the risk of particulate matter, ozone and pollen in respiratory disease, or provide advice during heatwaves to prevent heat-stress or exacerbations of existing illnesses.

Breadth of education: public health and eco-health literacy

Public health literacy has been described as *the degree to which individuals and groups can obtain, process, understand, evaluate, and act on information needed to make public health decisions that benefit the community ... with three dimensions: conceptual foundations, critical skills, and civic orientation*.⁵³ Bell describes a new literacy, eco-medical literacy, as *the ability to access, understand, integrate and use information about the health-related ecological effects of climate change to deliver and improve medical services*.¹¹ This can be further developed using eco-health perspectives. Eco-health approaches recognise the interdependence of human, animal and eco-system health and aim to develop transdisciplinary,⁵⁴ systems-focused collaboration to improve health through social stability and ecological sustainability.⁵⁵ This broadest conceptualisation of health, eco-health literacy, encompasses public health literacy and equips medical students with the tools to predict and manage human health in an uncertain ecological and socio-



Figure 1. A triad of outcomes for a climate change curriculum.

political future.

Calls for improved public health literacy in medical education are prominent and have a long history.⁵⁶⁻⁶⁰ This is based on the recognition that systems-focused, preventative, multidisciplinary approaches to health are crucial to address entrenched socio-economic and environmental disadvantage that still play out in health statistics. There has always been a tension between reductionist biomedical and broader public health paradigms. Yet medical education has been through several transformations and there is considerable momentum for a new transition,^{10,39,61,62} with approaches such as a three-pillared framework of basic, clinical and systems science,⁵⁷ or combined medical and public health qualifications.⁶³

In many instances, protecting public health and responding to climate change require synergistic skills: public health skills inform the health sector response to climate change and climate change can provide a lens to learn about public health. Developing sustainable, equitable, resilient health services and communities will require expertise across the spectrum of traditional public health domains:²⁹ health system administration, leadership and management; health policy and advocacy; health promotion and behavioural science; social and environmental determinants of health; epidemiology; ethics and professionalism; and occupational and environmental medicine.

Public health and eco-health literacy are not only essential to address climate change but are also essential to address other health pressures such as burgeoning rates of non-communicable diseases,⁵¹ ageing populations and untenable healthcare costs. As Lee *et al.* outline in their framework for health professional education, the *big picture* must inform curriculum design to be accountable to societal health needs.⁶⁴ Doctors have historically made significant contributions to public health debates and policy discussions. As *the greatest health threat of the 21st century*,⁵ it could be argued that a strong public health voice has never been more important. To this end, climate change could be a catalyst for greater public health and eco-health literacy.

Depth of education: existing learning and graduate attributes

While a climate change curriculum can broaden medical education to promote public health and eco-health literacy, it can also reinforce and deepen existing learning and promote higher-order learning and graduate attributes.^{12,65} Parallels between climate change and clinical practice, biomedical science and public health include: i) evidence-based practice: critical appraisal of climate change and health research; ii) heat-related illness pathophysiology: examining heat stroke and physiological risk; iii) infectious disease principles: examining climate-related shifts in vector borne disease; iv) statistics and epidemiology: exploring associations between respiratory disease and pollution; v) health as a human right: exploring challenges such as sustainable development and intergenerational equity; and vi) the value of multidisciplinary perspectives: appraising climate risks such as infectious disease and malnutrition from various angles, for example, agricultural and zoonotic studies.

Climate change also represents both a rationale and an opportunity to strengthen efforts to embed graduate attributes in medical education.⁶⁶ Graduate attributes underpin the process and outcomes of medical education and are transferable beyond professional practice.⁶⁷ Core attributes encompass knowledge, dispositions and skills and include: critical thinking, commitment to sustainability and ethics, and active global citizenship.⁶⁸⁻⁷¹ For example, at the University of Melbourne, students are expected to understand the relationship between environment and health, and commit to sustainable health-care and resolution of local and global health inequities. Such attributes are essential to progress on climate change and global health.^{57,60}

Climate change curriculum design

Discipline-specific pedagogical research is a relatively new field of inquiry and there are few models for health-professional curriculum development.⁶⁴ This paper builds on the four dimensions of a health curriculum outlined by Lee *et al.*: big picture context; learning objectives; teaching methods and assessment; and local administrative and institutional context.⁶⁴

Why? Big picture context

A climate change curriculum is necessary for workforce preparedness and could catalyse a transition in medical education. At the same time it can deepen existing learning and strengthen graduate attributes. This triad of outcomes are essential for future doctors to practice socially accountable and ecologically sustainable medicine.

What? Learning objectives

A challenge for medical educators will be prioritising learning objectives. A broad overview of climate change and health would provide scaffolding for future learning and help define relevant content. Conversely, an exploration of concepts and values is more likely to promote active and global citizenship, and engender appreciation of eco-health and public health lenses. To facilitate curriculum design that incorporates both of these perspectives, potential climate change content areas are described below, separated into factual, conceptual, skills-based and affective knowledge domains.

Factual knowledge: health risks, health co-benefits, health sector sustainability, social and environmental determinants of health, behaviour change, psychology of grief, community emergency response.

Conceptual knowledge: eco-health, equity, vulnerability, sustainability, planetary boundaries, precautionary principle.

Skill-based knowledge: clinical diagnosis and management of climate-related illness, health education, science communication, evidence-based practice, research, collaboration and systems-thinking.

Affective knowledge: appreciation of: the intricate relationship between equity, sustainability and health; the importance of medical training to broader society; and the benefits of multidisciplinary collaboration.

This paper proposes learning objectives that integrate climate change and health literature,⁸⁻¹⁴ pedagogical theory,^{65,66,72,73} and the authors' teaching and clinical practice experience (Table 1). In particular, the objectives incorporate perspectives from the Sustainable Health Education Network's priority learning outcomes on sustainability and health;¹⁴ Australian Medical Council standards,⁴⁹ and the Australia College of Rural and Remote Medicine curriculum competencies.¹¹ The objectives engage conceptual and affective learning; involve higher-order cognitive skills such as analysis, synthesis and evaluation; and expect students to apply this knowledge to the clinical context.

How? Teaching and assessment

It is beyond the scope of this paper to specify details of teaching and assessment. These will change with institutional, climate and medical contexts. Moreover, curriculum design is an ongoing process,⁷³ this is especially relevant in the dynamic field of climate change. However, key pedagogical considerations include constructive alignment, engagement, feedback, and assessment.

Climate change teaching could include lectures, placement projects, case based learning, reflective journals and clinical skills tutorials.⁷⁴⁻⁷⁶ Strategies to enhance engagement could include pre-learning, peer to peer teaching, panels and debates.⁷⁷ To facilitate agency in learning,

students should receive formative and summative feedback that is timely; relevant; and involves the student, teacher and peers.⁷⁸ Although learning objectives are the focus of this paper, assessment shapes student priorities and learning.⁷⁹ In a climate change curriculum, assessment should gauge higher order cognitive skills and conceptual, affective and skill-based knowledge as well as factual knowledge.^{65,72} To be transformative, a climate change curriculum needs to engage reflective learning processes that extend beyond the teaching context.⁵¹ However, to proceed to more reflective learning, and personal and professional development, students need to first be satisfied that the assessments are specific, relevant, and achievable.⁸⁰ Sample assessment items are outlined in Table 2. Further teaching resources can be found online at the Sustainable Healthcare Education Network.⁸¹

Where? Local implementation

It would be remiss to not acknowledge the potential barriers to integrating climate change into medical education. Challenges include: traditional bias towards biomedical reductionist paradigms; climate change denial; vested interests and politicisation of climate change;

insufficient resources for curriculum development; lack of climate change and health expertise; absence of a local *climate champion*;^{14,82} and a contested and tightly scheduled curriculum.⁸² Yet these barriers are becoming less significant as climate change and health concerns become more pressing.

Climate change could be incorporated in tertiary, vocational or continuing professional medical education. A tertiary climate change medical curriculum has the greatest scope to reach entire cohorts and enable standardisation across institutions. Furthermore, universities have been identified as potential catalysts for innovation and progress on climate change and health.^{39,71,83} As a confluence of expertise, universities can facilitate interdisciplinary collaboration in teaching and research,⁸⁴ which can provide graduates with diverse skills and perspectives necessary to address complex problems such as climate change.³⁹

The literature supports integrating climate change as core learning, both embedded in existing teaching,^{11,12} and introduced as stand-alone teaching.¹⁴ Embedding climate change in existing teaching – such as in a case-based tutorial on heatstroke – deepens and contextualises learning, strongly endorses climate change health concerns, and pro-

Table 1. Sample learning objectives for climate change and health.

Eco-health literacy	Outline the reliance of human health on local and global ecosystems; ^{11,14,48} Describe features of a healthy natural, social and built environment; ¹⁴ Identify populations where social and environmental determinants of health may interact to amplify risk; Incorporate knowledge of eco-health and planetary boundaries to justify priorities that promote both health and sustainability; Articulate an appreciation of the importance of sustainability to global health equity
Clinical climate change preparedness	Describe the mechanisms of direct, indirect, deferred and diffuse climate health risks; ^{13,14,49} Demonstrate competence in diagnosis and management of climate-sensitive and climate-induced illness; ^{11,13,31} Describe inter-sectoral collaboration to promote climate-change preparedness and emergency management; ^{11,32} Role-play consultations involving the prevention of climate-related illness and promotion of co-benefits of climate change mitigation; Identify resources for continuing professional education and evidence-based practice of climate-related illness ^{11,49}
Sustainable health systems	Define sustainability; ¹⁴ Explain how shifts in climate, natural resources, technology, economy and demography may affect the provision of healthcare in the future; ¹⁴ Apply systems thinking and multidisciplinary perspectives to develop strategies to promote health service sustainability; ¹⁴ Demonstrate a commitment to practice medicine sustainably and ethically ^{49,50}
Professionalism and public health literacy	Apply principles of active citizenship and professionalism to discuss doctors' responsibility to engage in advocacy and policy; ⁵¹ Acknowledge the ethical tensions in climate change contribution and vulnerability; ⁵¹ Apply critical appraisal and science communication skills to describe climate health risks; Articulate a commitment to resolving local and global health inequities ⁵⁰

Table 2. Sample assessments for climate change and health.

Group presentation	As a doctor representing the Fijian Government, outline the local climate and health issues and propose adaptation and mitigation priorities to the World Health Organisation's regional office. As a doctor representing the Australian Medical Association, discuss the health concerns of climate change and specify federal policy priorities on national radio.
Essay or in-class debate	Climate change is the greatest health threat of the 21st century. Climate change mitigation is more important than adaptation for health. Divestment from fossil fuels in an ethical and professional obligation of health services.
Reflective piece	Reflect on prominent public health successes to discuss the role of the doctor in advocacy and policy. Will climate change influence your personal and professional life, if so, how? Present a case history of a patient, identifying environmental and social determinants of health.
Short answer questions	List two direct, indirect and delayed health risks of climate change. Apply your understanding of vulnerability and determinants of health to explain how you would manage an elderly person living alone during a heatwave. Examine the following excerpt about a town in Bangladesh: what are its exposure, sensitivity and adaptive capacity to climate change? What priorities do you recommend to protect and promote health?
Placement project	Conduct a waste or energy audit of a clinic, ward or operating theatre and recommend strategies that promote health and reduce environmental impact. Conduct a review of a local council's processes to ensure the health of elderly residents during a heatwave or bushfire

notes permanence of the curriculum change. Conversely, stand-alone teaching enables students to conceptualise climate change and health in its entirety, and to adopt thinking styles that suit conceptual learning rather than factual-reductionist learning. Climate change and health can be taught from a variety of perspectives. A survey of UK medical schools found that climate change was taught mostly by public health specialists, but also by clinicians, ethicists, epidemiologists and climate scientists.⁸² Research indicates that teaching provided by a range of specialists conveys the relevance of climate change to all doctors.¹⁴

Further research

Further research could explore the relevance and transferability of this rationale and curriculum design to the education of other health professionals, and to different climate, socio-political and medical contexts. Gathering consensus among climate change and health experts on important learning objectives would complement existing research from the medical education perspective. Finally, reports of existing climate change medical curricula would assist with the practical aspects of curriculum design and implementation.

Conclusions

Climate change is serious issue threatening the viability of the ecosystems and socio-economic fabric sustaining human health. This paper has illustrated a rationale for including a climate change curriculum in medical education: for climate change preparedness; to promote public health and eco-health literacy; and to deepen learning and strengthen graduate attributes. This paper has proposed learning objectives and explored methods for teaching and assessment. Medical schools are encouraged to become leaders in this field to catalyse and support a strong public health response to climate change in order to secure a safe and sustainable future.

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References

1. Watts N, Costello A, Montgomery H, et al. Health and climate change: policy responses to protect public health. *Lancet* 2015;386:1861-914.
2. Rockström J, Steffen W, Noone K, et al. A safe operating space for humanity. *Nature* 2009;461:472-5.
3. McMichael T, Montgomery H, Costello A. Health risks, present and future, from global climate change. *BMJ* 2012;344:1359.
4. WHO. COP21 climate agreement. Moving towards healthier people and a healthier planet. 2015. Available from: http://www.who.int/globalchange/mediacentre/events/COP21_climateagreement_health/en/
5. Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. *Lancet* 2009;373:1693-733.
6. Barna S, Goodman B, Mortimer F. The health effects of climate change: what does a nurse need to know? *Nurse Educ Today* 2012;32:765-71.
7. Wang H, Horton R. Tackling climate change: the greatest opportunity for global health. *Lancet* 2015;386:1798-9.
8. Weaver HJ, Blashki GA, Capon AG, McMichael AJ. Climate change and Australia's healthcare system - risks, research and responses. *Aust Health Rev Publ Aust Hosp Assoc* 2010;34:441-4.
9. Hamel Green EI, Blashki G, Berry HL, et al. Preparing Australian medical students for climate change. *Aust Fam Physician* 2009;38:726.
10. Bell E, Horton G, Blashki G, Seidel BM. Climate change: could it help develop adaptive expertise? *Adv Health Sci Educ* 2012;17:211-24.
11. Bell E. Climate change: what competencies and which medical education and training approaches? *BMC Med Educ* 2010;10:31.
12. Wilcox B, Kasuya R. Integrating ecohealth into a medical school curriculum: a vision of the future at the University of Hawaii John A. Burns School of Medicine. *EcoHealth* 2004;1:34-42.
13. Bell E. Climate change: is Australian rural and remote medical education and training ready for the age of consequences? In: 10th National Rural Health Conference 2009. Available from: http://www.ruralhealth.org.au/10thNRHC/10thnrhc.ruralhealth.org.au/papers/docs/Bell_Erica_B7.pdf
14. Walpole SC, Mortimer F, Inman A, et al. Exploring emerging learning needs: a UK-wide consultation on environmental sustainability learning objectives for medical education. *Int J Med Educ* 2015;6:191-200.
15. Steffen W, Crutzen PJ, McNeill JR. The Anthropocene: are humans now overwhelming the great forces of nature. *AMBIO J Hum Environ* 2007;36:614-21.
16. Steffen W, Richardson K, Rockstrom J, et al. Planetary boundaries: guiding human development on a changing planet. *Science* 2015;347:1259855.
17. Haines A, Dora C. How the low carbon economy can improve health. *BMJ* 2012;344:1018.
18. McMichael AJ. Climate change: health risks mount while Nero fiddles. *Med J Aust* 2014;200:507-8.
19. Fritze JG, Blashki GA, Burke S, Wiseman J. Hope, despair and transformation: climate change and the promotion of mental health and wellbeing. *Int J Ment Health Syst* 2008;2:13.
20. Sachs JD. Climate change refugees. *Sci Am* 2007;296:43.
21. Tholken H. Politics and policies: making change happen. *BMJ* 2012;344:1356.
22. Hsiang SM, Meng KC, Cane MA. Civil conflicts are associated with the global climate. *Nature* 2011;476:438-41.

23. Patz JA, Kovats RS. Hotspots in climate change and human health. *BMJ* [Internet]. 2002 Nov 9 [cited 2016 Mar 29];325(7372):1094–8.
24. Haines A, Patz JA. Health effects of climate change. *JAMA* 2004;291:99-103.
25. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005;438:310-7.
26. United Nations Framework Convention on Climate Change. Climate change: impacts, vulnerabilities and adaptation in developing countries. Bonn, Germany: United Nations Framework Convention on Climate Change; 2007. p. 68.
27. McMichael AJ. The biosphere, health and sustainability. *Science* 2002;297:1093.
28. Demaio AR, Rockström J. Human and planetary health: towards a common language. *Lancet Lond Engl* 2015;386:e36-7.
29. McGain F, Blashki G, Moon K, Armstrong F. Mandating sustainability in Australian hospitals. *Med J Aust* 2009;190:719-20.
30. Power P. Australian healthcare services and the climate change debate. Canberra: Australian Healthcare and Hospitals Association; 2012. p. 14.
31. Karliner, J, Guenther, R. A comprehensive environmental health agenda for hospitals and health systems around the world. California: Global Green and Healthy Hospitals; 2011. p. 42. Report No.: 1.
32. Frumkin H, Hess J, Luber G, et al. Climate change: the public health response. *Am J Public Health* 2008;98:435.
33. NHS Sustainable Development Unit. Saving carbon, improving health. NHS Carbon reduction strategy. Cambridge: Sustainable Development Unit, National Health Service; 2009. p. 76.
34. Sustainable Development Unit. UN climate summit - cross system statement. 2014. Available from: <http://www.sduhealth.org.uk/policy-strategy/engagement-resources/un-climate-summit.aspx>
35. Armstrong F. Our uncashed dividend the health benefits of climate action. Camberwell: Climate and Health Alliance and the Climate Institute; 2012. p. 17.
36. Maro P, Smith D, Acquarone A. Acting now for better health: a 30% reduction target for EU climate policy. Brussels: Health Care Without Harm; Health and Environment Alliance; 2010. p. 40.
37. Larouche R. The environmental and population health benefits of active transport: a review. In: *Greenhouse gases - emission, measurement and management*. InTech 2012:28.
38. Bashmakov I, Bernstein L, Bogner JE, et al. Technical summary. In: *Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press; 2007. p. 70.
39. Lapaige V, Essiembre H. Innoversity in knowledge-for-action and adaptation to climate change: the first steps of an evidence-based climatic health transfrontier training program. *Adv Med Educ Pract* 2010;89-105.
40. Gómez A, Balsari S, Nusbaum J, et al. Perspective: Environment, biodiversity, and the education of the physician of the future. *Acad Med* 2013;88:168-72.
41. Blashki G, Armstrong G, Berry HL, et al. Preparing health services for climate change in Australia. *Asia Pac J Public Health* 2011;23:133S-43S.
42. McMichael AJ, Woodruff RE, Hales S. Climate change and human health: present and future risks. *Lancet* 2006;367:859-69.
43. Pandve H, Raut A. Assessment of awareness regarding climate change and its health hazards among the medical students. *Indian J Occup Environ Med* 2011;15:42.
44. Majra JP, Acharya D. Protecting health from climate change: preparedness of medical interns. *Indian J Community Med Off Publ Indian Assoc Prev Soc Med* 2009;34:317-20.
45. Nigatu AS, Asamoah BO, Kloos H. Knowledge and perceptions about the health impact of climate change among health sciences students in Ethiopia: a cross-sectional study. *BMC Public Health* 2014;14:1.
46. Vilella C. Climate change: what do doctors think? What can doctors do?: an international survey of general practitioners. Melbourne: The University of Melbourne; 2011.
47. Purcell R, McGirr J. Preparing rural general practitioners and health services for climate change and extreme weather. *Aust J Rural Health* 2014;22:8-14.
48. Cloeren M, Gean C, Kesler D, et al. American college of occupational and environmental medicine s occupational and environmental medicine competencies. *J Occup Environ Med* 2014;56:e21-40.
49. Australian Medical Council Limited. Standards for assessment and accreditation of primary medical programs. 2012. Available from: http://www.amc.org.au/files/d0ffcecd9608cf49c66c93a79a4ad549638bea0_original.pdf
50. The University of Melbourne Medical School. Course attributes. Melbourne Medical School. 2013.
51. Stoner L, Perry L, Wadsworth D, et al. Global citizenship is key to securing global health: the role of higher education. *Prev Med* 2014;64:126-8.
52. Hajat S, O'Connor M, Kosatsky T. Health effects of hot weather: from awareness of risk factors to effective health protection. *Lancet* 2010;375:856-63.
53. Freedman DA, Bess KD, Tucker HA, et al. Public health literacy defined. *Am J Prev Med* 2009;36:446-51.
54. Waltner-Toews D, Wilcox BA, Aguirre AA, et al. EcoHealth: a transdisciplinary imperative for a sustainable future. *EcoHealth* 2004;1:3-5.
55. EcoHealth. International Association for Ecology and Health. 2016.
56. Mello MJ, Feller E, George P, Borkan J. Advancing the integration of population medicine into medical curricula at the Warren Alpert Medical School of Brown University: a new master's degree program. *R I Med J* 2013;98:22-6.
57. Gonzalo JD, Haidet P, Papp KK, et al. Educating for the 21st-century health care system: an interdependent framework of basic, clinical, and systems sciences. *Acad Med J Assoc Am Med Coll* 2015. [Epub ahead of print]
58. Guicciardi S, Riforgiato C, Leopardi E. Students of today, physicians of tomorrow. Educational priorities for innovative teaching methods in medicine. *Recent Prog Med* 2015;106:72-3.
59. Orlando R, Haytaian M. Physician leadership: a health-care system's investment in the future of quality care. *Conn Med* 2012;76:417-20.
60. Stebbins S, Sanders JL, Vukotich CJ, Mahoney JF. Public health area of concentration. *Am J Prev Med* 2011;41:S237-41.
61. Frenk J, Chen L, Bhutta ZA, et al. Health professionals for a new century: transforming education to strengthen health systems in an interdependent world. *Lancet* 2010;376:1923-58.
62. Pearson D, Walpole S, Barna S. Challenges to professionalism: social accountability and global environmental change. *Med Teach* 2015;37:825-30.
63. Cooper SP, McCormick JB, Chappell CL, et al. Texas needs physicians trained in public health: a new 4-year integrated MD/MPH degree program. *Tex Med* 2010;106:e1.
64. Lee A, Steketee C, Rogers G, et al. Towards a theoretical framework for curriculum development in health professional education. *Focus Health Prof Educ* 2013;14:64-77.
65. Krathwohl DR. A revision of bloom's taxonomy: an overview. *Theory Pract* 2002;41:212.
66. Treleaven L, Voola R. Integrating the development of graduate attributes through constructive alignment. *J Mark Educ* 2008;30:160-73.

67. Barrie S. A research based approach to generic graduate attributes policy. *High Educ Res Dev* 2004;23:261-75.
68. Rigby B, Wood L, Clark-Murphy M. Review of graduate skills: critical thinking, team work, ethical practice and sustainability. Sydney: Australian Learning and Teaching Council; 2009. p. 25.
69. Hager P, Holland S, Beckett D. Enhancing the learning and employability of graduates: the role of generic skills. Melbourne: Business/Higher Education Round Table; 2002. p. 16.
70. Bowden J, Hart G, King B, et al. Generic capabilities of Australian Technology Network university graduates. Broadway: Australian Technology Network; 2000.
71. Orme J, Dooris M. Integrating health and sustainability: the higher education sector as a timely catalyst. *Health Educ Res* 2010;25:425-37.
72. Barnett R, Parry G, Coate K. Conceptualising curriculum change. *Teach High Educ* 2001;6:435-49.
73. Goodyear P, Dimitriadis Y. In medias res: reframing design for learning. *Res Learn Technol Suppl* 2013;21:19909.
74. Grose J, Richardson J. Can a sustainability and health scenario provide a realistic challenge to student nurses and provoke changes in practice? An evaluation of a training intervention. *Nurs Health Sci* 2015 [Epub ahead of print]
75. Hoover CR, Wong CC, Azzam A. From primary care to public health: using problem-based learning and the ecological model to teach public health to first year medical students. *J Community Health* 2012;37:647-52.
76. Richardson J, Grose J, Doman M, Kelsey J. The use of evidence-informed sustainability scenarios in the nursing curriculum: development and evaluation of teaching methods. *Nurse Educ Today* 2014;34:490-3.
77. Steinert Y, Snell L. Interactive lecturing: strategies for increasing participation in large group presentations. *Med Teach* 1999;21:37-42.
78. Nicol DJ, Macfarlane Dick D. Formative assessment and self regulated learning: a model and seven principles of good feedback practice. *Stud High Educ* 2006;31:199-218.
79. Biggs J. Enhancing teaching through constructive alignment. *High Educ* 1996;32:347-64.
80. Elton L, Johnston B. Assessment in Universities: a critical review of research. London: Learning and Teaching Support Network; 2002. p. 97.
81. Sustainable Healthcare Education. CSH networks. Available from: <http://networks.sustainablehealthcare.org.uk/network/sustainable-healthcare-education>
82. Tomes C. Teaching sustainable healthcare to tomorrow's doctors: a mixed method analysis of medical school innovations in England. Cambridge: University of Cambridge; 2011.
83. Vincent C, Batalden P, Davidoff F. Multidisciplinary centres for safety and quality improvement: learning from climate change science. *BMJ Qual Saf* 2011;20:i73-8.
84. Stordalen GA, Rocklöv J, Nilsson M, Byass P. Only an integrated approach across academia, enterprise, governments, and global agencies can tackle the public health impact of climate change. *Glob Health Action* 2013;6:20513.