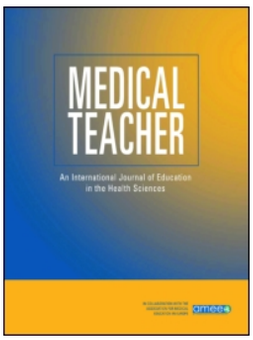

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What do tomorrow's doctors need to learn about ecosystems? – A BEME Systematic Review: BEME Guide No. 36

Sarah Catherine Walpole, David Pearson, Jonathan Coad & Stefi Barna

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BEME GUIDE

What do tomorrow's doctors need to learn about ecosystems? – A BEME Systematic Review: BEME Guide No. 36

SARAH CATHERINE WALPOLE[1], DAVID PEARSON[1], JONATHAN COAD[1] & STEFI BARNA[2]
[1]Hull York Medical School, York University, UK, [2]Norwich Medical School, University of East Anglia, UK

Abstract

Background: Human health is fundamentally determined by the health of ecosystems. Guidance is lacking about how to address the topic of ecosystems within medical education.

Aims: To determine the nature of discussions around ecosystems in the educational, medical and medical education literature. To identify learning needs of tomorrow's doctors.

Methods: A narrative synthesis approach was used. Systematic searches were completed in 14 databases. Two independent reviewers screened results. Preliminary synthesis included textual descriptions and quality appraisal. Data were analysed using the Education for Sustainable Healthcare framework and thematic analysis. Relationships between studies were explored. Best evidence synthesis, contacting authors of primary studies and critical reflection reinforced robustness.

Results: Six thousand seven hundred and fifty-three abstracts and 123 full texts were screened. Twenty-seven studies were included. Many studies lacked clear reporting. Medical students and doctors displayed knowledge about ecosystems, but lacked confidence to enact sustainable practices. Education about causes and consequences of environmental change is required. Few studies proposed specific learning objectives.

Conclusions: To prepare for roles as health care workers and leaders, medical students must learn about relationships between ecosystems, health and health care. The Education for Sustainable Healthcare framework outlines essential knowledge and attitudes but requires addition of practical competencies. Further research should explore the framework's relevance in different contexts, in order to structure training accordingly.

Background

> Nature's goods and services are the ultimate foundations of life and health. Jong-Wook Lee (piii, Corvalan et al. 2005)

Over the last two centuries, our ability to master the relationship between humans and the natural environment has produced dramatic improvements in life expectancy and health. Concurrently, technological advances have created new, often transnational, health hazards whose burden is distributed unequally between populations (Watts et al. 2015).

Human health depends on the health of ecosystems (Lang & Rayner 2012). Anthropogenic ecosystem disruption is a major cause of morbidity and mortality globally (Corvalan et al. 2005). All natural materials that humans use are taken from ecosystems (Gómez-Baggethun et al. 2013), all synthetic materials are derived from ecosystems, and all waste produced (solid, liquid and gas) is returned to the ecosystem (Beaumont et al. 2007).

This review is framed around the World Health Organisation's definition of ecosystems:

> a naturally occurring community of organisms, such as plants and animals, together with their environment, functioning as a unit. (WHO 2013)

The World Medical Association states that medical professionals should be aware of the impacts of environmental change on the health of individuals, communities and societies (WMA 2009). The UK's General Medical Council prompted a national consultation which led to the

Practice points

- Tomorrow's doctors must understand the relationship between ecosystems and human health.
- Tomorrow's doctors require competence to enact environmentally sustainable practices, including measuring and managing the ecological footprint of health care and advocating about environmental and health issues.
- The Education for Sustainable Healthcare framework can guide curricula and teaching development.
- Research and evaluation should investigate how teaching about ecosystems can meet local needs and priorities.

Correspondence: Sarah Catherine Walpole, Hull York Medical School, York University, Heslington, York YO10 5DD, UK. E-mail: sarah.walpole@hyms.ac.uk

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development of priority sustainability learning objectives (Thompson et al. 2014).

Education has a central role to play in understanding the environmental determinants of health and preparing individuals and societies to address environmental issues (Orme & Dooris 2010; Sterling 2012). Medical education is currently structured around the physiological and social determinants of health. The structure could be extended to include effects of local, regional and global ecological systems on health. Education on issues such as biodiversity, climate change and disaster risk reduction can foster development of new, creative pedagogies in education and enhance learning of other topics (UNESCO 2012).

Aims

(1) To determine the nature of discussions around ecosystems in the international educational, medical and medical education literature.
(2) To establish the nature and quality of the arguments for inclusion of ecosystems in medical education.

Objectives

(a) To identify the terms and contexts used to discuss ecosystems in relation to medicine and medical education by carrying out systematic literature searches.
(b) To identify the arguments for and against the inclusion of ecosystems in medical education, and organise these findings using a systematic framework.
(c) To explore the explanations given to support arguments to include/exclude ecosystems as a topic in medical curricula.
(d) To develop recommendations for educational practice based on the results of the synthesis.

Methods

Definition of review question

This review explores arguments about whether tomorrow's doctors should learn about ecosystems and what learning needs tomorrow's doctors have. This review does not investigate *how* doctors should learn, because it is best to explore effective pedagogies *after* learning goals have been defined (Belfield et al. 2001).

This is primarily a 'definitional review', identifying how ecosystems are described in relation to medical education; but also a 'scoping review', exploring the extent of the literature.

The review protocol set clear but broad limits for inclusion of papers to avoid relevant data being excluded. The terms 'ecosystem' and 'ecological' are used according to the WHO definition, thereby incorporating 'environment' and 'environmental' respectively.

The review population is described as 'tomorrow's doctors' (after the UK medical curriculum document (GMC 2009)) and includes current and future doctors. Doctors are defined as those holding a degree in Medicine from any country. Health professionals have different learning needs (Parsell & Bligh 1998); this review only investigates the needs of doctors. Theories or evidence from other health professions are included, because they may inform understanding of tomorrow's doctors' learning needs (Harden et al. 1999). Professions related to health care but with very different training or professional duties are not included in the review (see exclusion criteria below).

Learning needs are defined here as 'the discrepancy or gap between the competencies specified... and their present level of development by the learners' (after Knowles et al. 2005, p. 125). We consider the knowledge, skills, attitudes or attributes which need to be acquired by students to fulfil the required capabilities and roles as professionals.

Consideration was given to identification of *lack* of need, i.e. literature opposing the inclusion of the ecosystems topic in medical education. This could be explicit (e.g. studies of opinion concluding that learning is not required or experimental evidence showing no impact or negative impact of learning about ecosystems) or implicit (e.g. curricular recommendations that do not mention ecosystems).

Type of synthesis

Based on scoping studies, it was anticipated that there would be a small number of papers, but diverse methodologies and settings. Narrative synthesis can be applied to studies with such diversity. Methods were informed by Economic and Social Research Council (ESRC) guidance on narrative synthesis reviews of implementation or effectiveness (Popay et al. 2006) and Centre for Reviews and Dissemination (CRD) guidance on systematic reviews (CRD 2009). This review represents a methodological adaptation of ESRC guidelines (for more details see Appendix S1, published online as Supplementary Material), because its question is not *how to implement* education or the *effectiveness* of education but *what* needs to be learnt. Table 1 outlines elements of narrative synthesis, and where there have been adaptations of the ESRC guidance for the purposes of this systematic review.

SW led the design, searching, screening, analysis and evaluation. DP oversaw the project and contributed to consensus about inclusion/exclusion. JC trialled screening criteria, screened search results, appraised quality, and abstracted data from a sample of studies. SB contributed to protocol design. All authors contributed to writing the final manuscript.

Searching

Relevant seminal papers and expert opinion were used to identify key terms (see Appendices S2 and S8, published online as Supplementary Material). A search strategy was developed in OVID Medline. The 'OR' operator was used to pool results for population and for topic. The 'AND' operator combined results from both pools (see Appendix S3, published online as Supplementary Material). The search strategy was validated by verifying that key papers (identified *a-priori*) appeared in the search results, and reviewing a sample of 100 results for relevance. The strategy was translated into 13 other databases (Appendices S3 and S4, published online as Supplementary Material). Searching in non-Latin alphabet databases was not possible due to resource limitations.

Table 1. Elements of narrative systematic review, informed by Popay et al. (2006, p. 11).

Element of synthesis	Approach in implementation reviews	Variations from ESRC guidance wit reasons
1. Developing a theoretical model of how the interventions work, why and for whom	Inform decisions about review question, aid interpretation of findings, assess applicability of findings	As no intervention was being evaluated, a theoretical model was not used to inform design of the research question or assess applicability of findings. Instead, a framework to aid organisation of findings was identified after the question was defined.
2. Developing a preliminary synthesis	Organise findings to identify facilitators and barriers to implementation	Findings organised according to the aspect of ecosystem–health linkages (using framework). As there were minimal data arguing against the inclusion of curricular topics, the focus was on different arguments for inclusion of education about aspects of ecosystems. Due to the framework not being sufficient to encompass all findings, thematic analysis was also used to organise findings that did not fit within the framework.
3. Exploring relationships in the data	To explain differences between findings, and understand why interventions are effective	As per ESRC guidance, refutational translation and moderator variables were used to explore differences between findings; helping to understand why arguments are made for inclusion of education about aspects of ecosystems.
4. Assessing the robustness of the synthesis	To provide assessment of strength of evidence and generalisability	Quality appraisal was not carried out during screening because the only studies excluded due to quality were opinion and comment pieces. Discussion of quality of included studies was therefore a particularly important element of the assessment of synthesis robustness. Critical appraisal of the review process and checking the product of synthesis with authors of primary studies was carried out in line with ESRC guidance.

To maximise search sensitivity, no limits and no exclusion based on language were applied. Studies of any design, in any setting (e.g. clinical/non-clinical, any geographical location), with any (or no) outcome measure were sought. Papers from 1993 onwards were included.

Further literature was identified via experts (Appendix S8, published online as Supplementary Material) and authors of included papers.

Screening

Screening criteria were developed and piloted by two researchers (SW, JC) on 100 papers to verify clarity and usability, with criteria subsequently amended based on the pilot. The final criteria were:

POPULATION – INCLUSION:

- Medical students at any stage of training
- Doctors at any stage of training in any specialty, including clinical pathology or microbiology
- Student or qualified nurses and allied health professionals
- Student or qualified dentists
- Regulated complementary health care practitioners, e.g. chiropractors

POPULATION – EXCLUSION:

- Social workers
- Health care assistants
- Community health care workers
- Complementary therapists not registered with a professional body, e.g. flower remedy providers, shamanic healers
- Veterinary medicine students
- Health care managers
- Policymakers, apart from public health doctors

INTERVENTION – INCLUSION:

- Education
  - intervention aiming to facilitate learning of knowledge, concepts, skills, behaviours or attitudes
  - development of learning objectives or curricula
- Topic of ecosystems
  - interactions between a community of organisms (more than two species, one of which may be humans)
  - interactions between organisms and the local ecosystem, including human and health care influences, e.g. on rivers, woodland or parks via reforestation or pollution
  - global environmental change, including anthropogenic
  - environmental sustainability/preservation of ecosystems, including sustainable health care

INTERVENTION – EXCLUSION:

- Education
  - interventions in the educational environment which do not primarily aim to enhance learning, e.g. measures to improve student well-being, admissions procedures, cost-saving measures
  - studies about pedagogy, not content, i.e. studies that discuss how teaching should be delivered, not what should be taught or why
  - interventions aiming to enhance learning generally, i.e. not specifically to enhance learning about ecosystems, e.g. improvement of facilities or virtual learning environment
- Topic of ecosystems

- exclusively about the human species, e.g. focusing on human physiology
- human-made organisations, products, structures or systems, without discussion of relationship with ecosystems
- interactions of communities of organisms at microscopic level, including bacteria or viruses
- disease vector and parasite control, unless related to wider ecosystem
- management of adverse weather events and disaster preparedness, unless explicitly related to ecosystem change

COMPARATOR
- No comparator required

OUTCOMES
- No restrictions

STUDY DESIGN – INCLUSION:
- Systematic reviews; meta-analyses;
- Expert consensus; policy documents;
- Studies exploring learning needs, including trials or observational studies;

STUDY DESIGN – EXCLUSION:
- Comments; opinion pieces; letters and literature reviews, unless bringing to light new evidence or reporting on consensus or recommendations
- Case studies of implementation of teaching, unless evaluating effect of learning about ecosystems

SETTING
- No restrictions.

LANGUAGE
- No restrictions.

Screening took place in three stages. First, the title and abstract of all papers, which could not be downloaded into the database software (Appendix S6, published online as Supplementary Material) were screened by one researcher (SW), to exclude results that were clearly irrelevant. The remaining results from these databases and all other results were de-duplicated into open-access database software (MendeleyTM). Further papers identified by experts were added to the database. The title and abstract of all results were screened independently by two researchers (JC, SW). Any paper included by either author was retained.

Second, two reviewers (SW, JC) worked together to scrutinise the abstracts of all remaining results. Further papers not meeting the inclusion criteria were excluded. The vast majority of non-English language studies provided English language abstracts, and for those that did not online translation tools were employed.

Third, the full text of all remaining results was sought. Two researchers (JC, SW) independently screened the full text of all papers. Translation support was employed as required for screening of full papers. Three researchers (DP, JC, SW) discussed all papers and achieved consensus on whether each paper met the inclusion criteria.

Data abstraction

One researcher (SW) abstracted data meeting the inclusion criteria using line-by-line review (Holton 2007). A second researcher (JC) abstracted data from one study from each of the three main groupings (selected using a random number generator[1]). Abstracted data from each researcher were compared to verify reliability of the approach.

Data analysis, appraisal and synthesis

Qualitative data management software was not used as it may emphasise the frequency with which findings appear over the strength of the evidence and does not necessarily produce a more valid or reliable product of synthesis (Pope et al. 2000; St John & Johnson 2000). Such software is better suited to reviewing larger quantities of data (Pope et al. 2000; Thorne 2000; Humble 2012). Translators provided cultural and linguistic insights for Chinese, Portuguese, Russian and Spanish papers.

Theoretical framework

After extensive literature review and canvassing of experts, only one appropriate framework was identified – the Education for Sustainable Healthcare Learning Objectives (Figure 1). Two authors (SW, SB) were involved in its development; which brings benefits of increased understanding of and ability to apply the framework, but risks that background knowledge may induce assumptions about how findings relate to the framework.

Preliminary synthesis

Reading of the included studies guided decisions about tools for the preliminary synthesis. Tabulation and textual descriptions of studies were informed by multiple readings of individual studies (SW, DP).

Grouping according to study design highlighted patterns in the data and facilitated translation of findings. Tabulation mapped each paper's context, date, design, participants, methods, outcome measures (if any), strengths and weaknesses.

Two researchers (SW, JC) independently analysed study quality using a four-question tool (Dixon-Woods et al. 2006) based on Kangasniemi et al. (2014). Discrepancies were discussed with reference to the wider literature (SW, JC). This tool was chosen because it provides an overview of key aspects of study quality. It had three main limitations when applied to this synthesis:

(1) Questions have variable relevance dependent on study design, e.g. whether the writers' and sponsors' aims, methods, analysis and supporting data are reported may have less impact on the strength of evidence from position papers than on that from observational studies.
(2) Questions have variable ability to describe the contribution of each paper to this evidence base (Yardley & Dornan 2012); e.g. methods and reporting may be clear and appropriate, but the paper may provide only limited

[1]http://www.random.org/integers/ (accessed 16 November 2014).

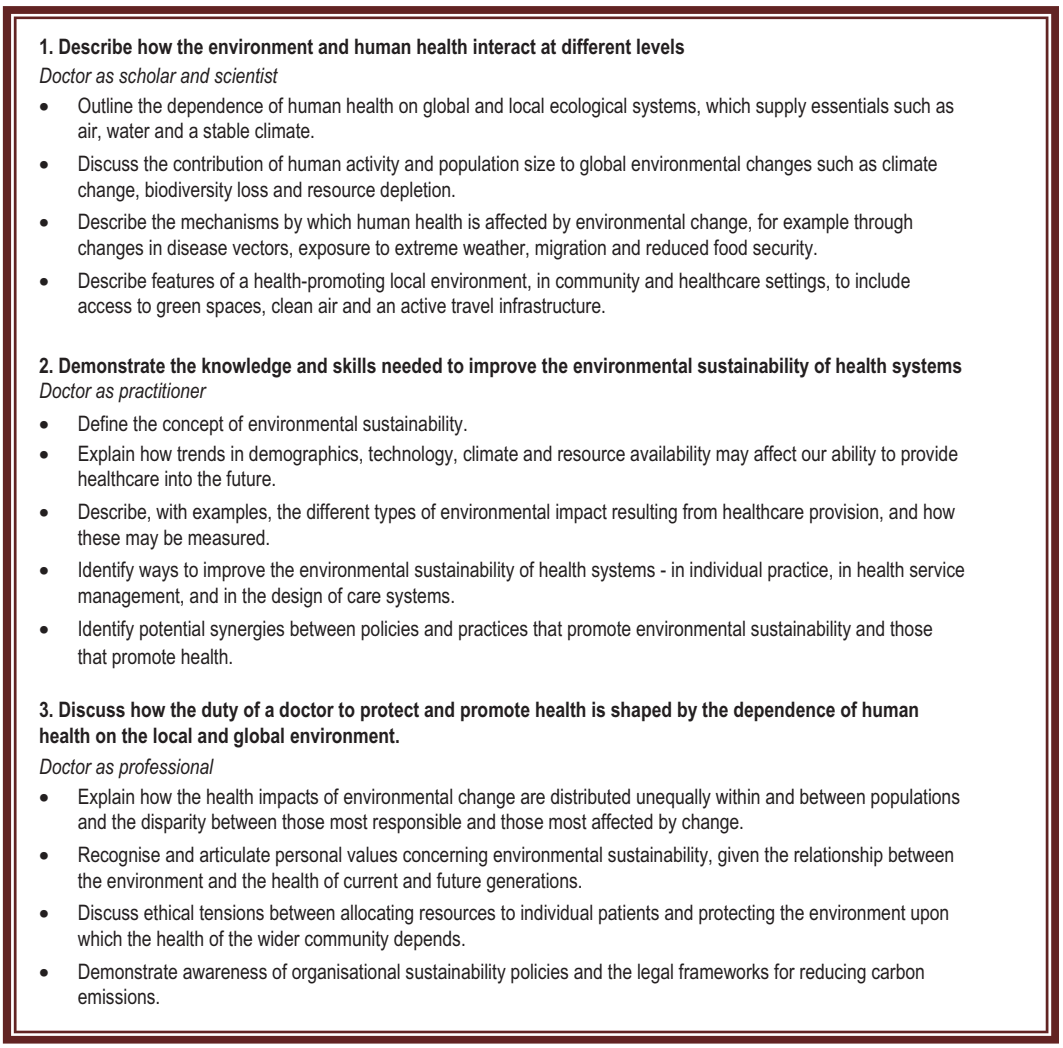

Figure 1. Sustainable Healthcare Education network Priority Learning Objectives (Thompson et al. 2014).

insight if the focus of the study is not in line with the research question.

(3) It is difficult to answer 'yes' or 'no' to some questions, because there is a grey area when papers meet the criterion to some extent or in part of the study. (In these cases, consensus between two researchers was achieved through discussion.)

A second quality appraisal tool was therefore used. Quality assessment with Critical Appraisal Skills Programme (CASP) (2014) criteria provided richer insights into study quality.

Sentence-by-sentence coding of abstracted data highlighted definitions and terms used, and informed clustering of data around the theoretical framework (SW). Deductive analysis using the *a-priori* framework was complemented by inductive thematic analysis of findings, which did not fit within the framework. Thematic analysis involved re-reading data to identify themes, then re-reading data again to code findings under the themes (SW). A table of conclusions, strengths and weaknesses highlighted the frequency with which conclusions were reached.

Exploration of relationships between studies

Exploration of relationships between the studies involved translating findings between studies, concept mapping and moderator variables. Reciprocal and refutational translation of findings between studies was carried out informed by clustering studies and thematic analysis. Key concepts were identified and relationships explored. Data were considered in the light of the study's design, context and population to explore how reasons for differences between findings.

Evaluation of robustness of the synthesis

Weight of evidence was assessed using Dixon-Woods et al.'s (2006) quality appraisal checklist and CASP as described above. The product of synthesis was evaluated in the light of quality appraisal findings.

Authors of each primary study were invited to recommend further studies for inclusion, and assess the accuracy of interpretation of their study and the extent to which the synthesis product reflects their study's findings. Responses were used to validate review findings and evaluate the strength of review conclusions.

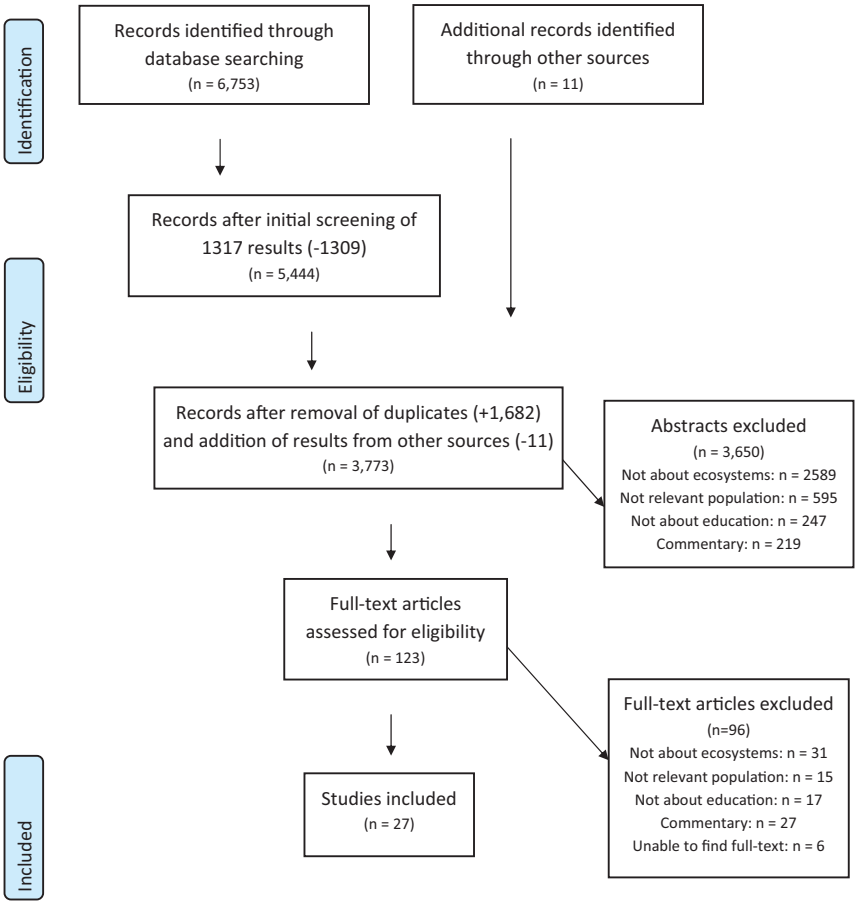

Figure 2. Searching and screening, PRISMA Flow diagram (Moher et al. 2009).

Critical reflection was facilitated through record keeping and reflective diary writing. It involved revisiting the review process to consider strengths and weaknesses.

Results

Systematic searches identified 6753 results from 14 databases (see Appendix S9, published online as Supplementary Material).

After initial screening 1309 results were removed. A further 1682 duplicates were removed and 11 studies identified from other sources were added, leaving 3773 abstracts. 3650 results were excluded during screening of abstracts, leaving 123 results. Six papers could not be obtained (Appendix S5, published online as Supplementary Material), leaving 117 full texts that were screened. 27 were included in the final analysis (Figure 2). No further papers were included following contact with authors to identify other relevant papers.

Appendix S10, published online as Supplementary Material, describes the characteristics of included studies. Three categories of study design were identified inductively: six papers present expert consensus or recommendations from a professional body (hereafter, 'position papers'), eight describe evaluation of an educational intervention, thirteen investigate stakeholder opinions or knowledge of health care professionals.

Clustering data according to terms and definitions

In the preliminary synthesis, data were clustered according to terms and definitions used.

The most frequently used terms were 'environment' (and 'environmental'), 'ecosystem' (and 'ecological'), 'environmental change', 'climate change' and 'sustainability' (and 'sustainable'). Many papers discuss the meaning and scope of key terms, and highlight the variety of meanings and the challenges of standardised definitions. Many authors define environment broadly, e.g. as 'that which is external to the human being' (de Souza Bruzos et al. 2011, p. 463). Some studies investigate participants' understanding of concepts. Health professionals in a Brazilian study variously define environment narrowly (focusing on their hospital environment) or broadly (looking beyond the hospital) (Camponogara et al. 2009).

The language employed suggests that authors or participants hold positive or negative perspectives on ecosystems. Terms that imply positive relationships with ecosystems include 'ecological care' (Koerich et al. 2010) and 'sustainable' or 'sustainability', which describe human practices that do not harm nature (e.g. AACN 2011). Conversely, negative connotations of ecosystems are highlighted with terms such as 'ecological problems' (e.g. Camponogara et al. 2009), 'human induced environmental degradation' (Truckner 2009) and 'preparedness' for health threats and hazards such as climate

change (WNA 2008; Bedsworth 2009; Pandve & Raut 2011). A consensus statement discusses 'unprecedented threats to human health' from 'global environmental changes' (Hollan et al. 1998, p. 70). The term 'natural' contrasts 'human', highlighting tensions between humans and nature (e.g. Viero et al. 2012).

Arguments for and against addressing ecosystems as a topic in medical education

Simple vote counting, in the form of a table of conclusions, strengths and weaknesses of each study (see Appendix S11, published online as Supplementary Material) highlights that there are gaps in health professionals' and students' knowledge and understanding of ecosystems. The second most common conclusion is that more teaching about ecosystems should be included in health professional education. This table should be interpreted with caution and should not be used to estimate direction of effect for three reasons: (1) poor quality papers were not excluded, (2) many studies have limited generalisability/transferability (e.g. due to study size or recruitment methods), and (3) included studies are very diverse in design, population, context, intervention and outcome measures, therefore pooling results is not appropriate.

No papers suggest topics or competencies related to ecosystems that should not be taught. Further exploration of the quality of arguments and findings of the synthesis is discussed below.

Students and educators expressed that universities have a duty (which they are not fulfilling) to instil environmental values in students (Koerich et al. 2010). Nurse educators state that universities and educators have a responsibility to widen students' perspective and educate students about ecosystems (Viero et al. 2012).

Arguments clustered according to the theoretical framework

Describe how the environment and human health interact at different levels

Doctors, students and educators believe that health professionals must understand interdependence between ecosystems and humans (Silva et al. 2010; de Souza Bruzos et al. 2011). Many doctors are asked by patients about environmental issues and/or see examples of environmental problems impacting patients' health, suggesting environmental topics are highly relevant (Truckner 2009).

Six papers document expert consensus or recommendations by professional bodies or conferences; four including statements supporting education of health professionals about ecosystems and two proposing specific competencies. The American Association of Nursing Colleges (AACN 2011), an international expert consensus (Hollan et al. 1998) and the World Nursing Association (WNA 2008) state that health professionals should understand and inform colleagues about global environmental change. The Royal Colleges of Physicians of UK (RCP 2010) states that doctors should understand greenhouse gases emissions associated with health care services. Conference working groups recommend education about environmental stewardship (Medlin & Grupenhoff 2000) and environmental exposures (Blockstein & Mcmanus 2007). These papers are accorded a higher degree of representational and inferential generalisability due to the expertise of the individual authors or organisational endorsement; however, they are not transparent about methods used and influences on authorship and process. These papers suggest that tomorrow's doctors should learn about global environmental change, the relationship between the environment and human health and management of environmental impacts of health services.

Public health registrars suggest information about the 'basic science' of climate change is useful to them:

> 'Clarifying climate change terms and examining the basic science . . . were rated by participants as among the "most useful" parts of the workshop.' (Charlesworth et al. 2012, p. 28)

One study tests general practitioners' (GPs), medical educators' and medical students' ability to answer questions about specific environmental issues (land degradation, sanitation, water contamination, deforestation and biodiversity); implying that these issues are relevant to tomorrow's doctors (Cabrera & Tomey 2010). The study concludes that knowledge is lacking, and further education is needed. Another study asks health professionals to rank the importance of environmental issues, finding that they give air pollution and population growth high priority and climate change low priority (Truckner 2009).

No studies explore and compare students, doctors or other stakeholders rating of the priority of different topics related to ecosystems. Knowledge deficits are identified in multiple areas highlighting that, if there is a need for tomorrow's doctors to understand these issues, further learning is required.

Demonstrate the knowledge and skills needed to improve the environmental sustainability of health systems

It is recommended that doctors learn about 'the implications of their healthcare decisions on greenhouse gases emissions' (RCP 2010, p. 5). The American Association of Colleges of Nursing recommends that nurses learn about 'reducing healthcare's biological, chemical and physical waste stream' (AACN 2011, p. 4), 'resource stewardship in clinical settings' (AACN 2011, p. 8) and using 'healthcare resources in a judicious and thoughtful way' (AACN 2011, p. 9). They state that:

> 'students educated today will need to critically re-examine the resource intensive aspects of the health care system.' (AACN 2011, p. 4)

and suggest that nursing students need to be 'capable of designing and implementing sustainability initiatives in hospitals and clinics' (AACN 2011, p. 10). A biomedical conference recommends that research students learn about

'environmental stewardship' (Medlin & Grupenhoff 2000, p. 946). The American Association of Colleges of Nursing also recommends that deans and nursing school faculty learn about environmental sustainability (AACN 2011).

Many studies focus on one aspect of health care's ecological footprint. Two action research projects (Takayanagui 1993; Laustsen 2005) and three surveys (Punchanuwat et al. 1998; Doerr-MacEwen & Haight 2006; Corrêa et al. 2007) focus on waste management in health care services. In Laustsen's project (2005), participants themselves select waste management as the environmental issue to address. Four studies identify knowledge deficits among health care workers which result in unsustainable practices (Takayanagui 1993; Punchanuwat et al. 1998; Laustsen 2005; Corrêa et al. 2007). Two studies find that interventions including education of a small group of participants result in improved practice (Takayanagui 1993; Laustsen 2005).

Researchers from China selected energy consumption as a priority issue for health care facilities because of cost and government policy (Su et al. 2011). Their research identifies deficits in health care workers' knowledge about energy consumption. The study identifies a programme of multiple interventions, including education of the multidisciplinary team, as effective in improving practice, but due to confounding, offers only weak evidence that education may improve knowledge.

Two studies provide more credible evidence that educating doctors can result in small improvements in environmental behaviours. Fogarty et al. (2008) identify a modest but positive impact of educating GPs about improving the environmental sustainability of the health service. Charlesworth et al. (2012) show that education of public health registrars about environmental change resulted in improved knowledge and advocacy scores, with 6 of the 26 participants delivering teaching about environmental issues three months post-intervention.

Authors of one study suggest that a useful concept for clinicians is that health benefits may arise as a positive side effect of choosing environmental behaviours (however this finding seems to be based on prior experiences, not the included study):

> 'The Sustainable Development Unit has found that most clinicians and general practitioners respond best to the health co-benefits argument (that is, that a low-carbon lifestyle is a healthy lifestyle).' (Charlesworth et al. 2012, p. 29)

Discuss how the duty of a doctor to protect and promote health is shaped by the dependence of human health on the local and global environment

Findings suggest that a 'holistic' view of environmental issues allows health professionals to address these issues effectively and appropriately (Camponogara et al. 2009; Koerich et al. 2010).

Many studies relate ecosystems thinking to values, such as 'the importance of a social contract with society' (Villela et al. 2008, p. 277) or the 'responsibility to care about the planet' (AACN 2011, p. 12). One health care student suggests that education about ecosystems should help learners to develop values:

> 'Concientizacao ambiental entra nesse resgate de valores de como realmente tratar as pessoas.' (Koerich et al. 2010, p. 6) (*Environmental awareness rescues values such as how really to treat people*)

Nursing educators and students suggest that learning about one's personal values may results in an individual acting more appropriately in relation to environmental issues (Silva et al. 2010; Viero et al. 2012). There is variation in the extent to which health professionals and students have developed opinions and values in relation to ecosystems (Corrêa et al. 2007; Koerich et al. 2010; Silva et al. 2010; Viero et al. 2012). No papers recommend a need to learn to articulate personal values.

One study suggests a need to learn the 'delicate balance between health and the environment' (Camponogara et al. 2012, p. 391); no other studies suggest a need for learning about tensions between use of resources to promote an individual's health and reducing resource use to protect the environment.

Only one study discusses health equity. Based on questionnaire responses from nursing students, Silva et al. (2010, p. 42) recommend health professionals learn about the relationship of ecosystems with equity as a route to building 'a more humane and just society' ('construindo uma sociedade mais humana e justa'). The same study suggests health care students should be educated about the relationship between environmental issues and law (Silva et al. 2010). Another study recommends health professionals should have an understanding of 'the country's legal framework' ('los documentos legales del pais'; Cabrera & Tomey 2010, p. 452).

Thematic analysis

Thematic analysis was used to explore data that was not coded according to the framework. Three themes emerged.

Relationship between learning and action

Where knowledge about ecosystems is lacking, health professionals are less likely to enact environmentally sustainable practices. One reason that health professionals did not improve waste management practices was a lack of knowledge (Laustsen 2005). Public health officers indicate a need for more knowledge to be able to design and enact responses to environment problems (Bedsworth 2009). One study suggests that nurses need 'knowledge of science and of society so that they can practice well' ('conhecimento cientifico e humano, para que possamos trabalhar bem na pratica'; Silva et al. 2010, p. 39).

Developing environmental consciousness through education may effect positive changes, for example improved energy-saving behaviours (Su et al. 2011) and better waste management practice (Takayanagui 1993). Learning may improve practice by motivating individuals, increasing their 'environmental responsibility' (Camponogara et al. 2009,

p. 1034) and making them feel more confident to make changes (Viero et al. 2012).

Some studies, however, suggest that consciousness alone is not enough to bring about environmental behaviours. Lack of supportive government policies (Camponogara et al. 2012) and pressure from corporations (Doerr-MacEwen & Haight 2006) can be barriers to enacting environmental actions. The five studies that measure a change in practice are those that train participants about specific actions that they can take (Takayanagui 1993; Laustsen 2005; Fogarty et al. 2008; Su et al. 2011; Charlesworth et al. 2012). Three provide support to participants during implementation of actions (Takayanagui 1993; Laustsen 2005; Su et al. 2011).

Informing colleagues and the public

Informing colleagues and the public is a key health professional role. A consensus of scientists and health professionals states that health professionals must inform their colleagues about global environmental change (Hollan et al. 1998). Takayanagui's (1993) action research project is based on her premise that nurses have a role in informing other health workers.

Nurses should communicate environmental issues to colleagues and the public in order to increase awareness and promote environmental behaviours (AACN 2011). A survey finds that family-planning workers would like to be able to communicate environmental issues to patients effectively (Worthington et al. 2010).

Education in the context of other strategies to protect ecosystems

Education needs to be part of a more holistic strategy to improve practices in waste management (Takayanagui 1993; Corrêa et al. 2007) and energy efficiency (Su et al. 2011). A committee recommends that education must occur alongside research and policy development (Medlin & Grupenhoff 2000). Education of health professionals can promote debate, discussion and understanding of ecosystems among health workers and in society (e.g. Camponogara et al. 2009).

Key stakeholders believe that educating doctors about rational prescribing would be valuable to reduce pharmaceutical pollution and improve health (very 'effective'), but motivating changes in prescribing practices is very difficult because of the influence of pharmaceutical companies who promote prescribing (only 'moderately feasible') (Doerr-MacEwen & Haight 2006). In contrast, of medical students surveyed, 88.5% believe education is 'the most effective strategy', from a range of options to address the health impacts of climate change (Pandve & Raut 2011).

Summary of findings

Tomorrow's doctors need to learn about theory and practice relating to ecosystems; understanding this may support or be enhanced by learning about the implications for practice (Charlesworth et al. 2012; Viero et al. 2012).

By way of theory, they should understand concepts relating to ecosystems, including ecosystem interactions and relationships with human health. Many studies discuss *competencies* that health professionals need to acquire. Learning about ecologically sound practice can be achieved experientially (e.g. through developing and delivering practical interventions to change behaviour (Takayanagui 1993; Laustsen 2005) or through theory-based teaching about ecological policies and behaviours (e.g. Fogarty et al. 2008; Charlesworth et al. 2012). The need for knowledge and practical competence emerged from the findings and is represented in the conceptual map (Figure 3), which was created to summarise the review findings.

The next section explores the quality of arguments for and against inclusion of these topics in medical education.

Exploration of the quality of arguments

Quality analysis using two tools identified that most studies were of poor quality; providing data from a small, self-selected and/or undefined population and not providing sufficient evidence to support their conclusions (Appendices S11 and S12, published online as Supplementary Material). Many studies did not report methods clearly, in particular, the methods used to analyse data and derive main findings from qualitative data. Many studies lacked discussion of reflexivity, which hindered differentiation of the researchers' opinions from study finding.

All 27 studies provide qualitative data; nine also provide quantitative data. Of studies collecting quantitative data about knowledge and attitudes, only one used a validated data-collection tool.

Studies carrying out pre- and post-intervention evaluations do not include a control or account for the effect of repeat testing. Four studies compare self-reported knowledge or attitudes before and after an educational intervention, of which three identify increased correct responses to a knowledge test after intervention (Villela et al. 2008; Worthington et al. 2010; Su et al. 2011) and two identify more environmental attitudes (Villela et al. 2008; Charlesworth et al. 2012). Two studies ask respondents to compare their environmental practices before and after an educational intervention (Fogarty et al. 2008; Charlesworth et al. 2012).

Seven papers met all five Dixon-Woods et al. (2006) quality criteria and seven (including all six position statements) met zero or one criterion. Apart from position statements, the majority of studies define aims, methods and an appropriate research design. Fewer papers (but still a majority), provide adequate description of methods of analysis used. Most papers provide sufficient data to support their conclusions, but the conclusions have variable applicability to this review question. Two reviewers concurred about quality of the studies appraised in the majority of cases. The few discrepancies were mainly about clarity of reporting in position papers (see Appendix S12, published online as Supplementary Material).

While this quality appraisal provided a useful overview, appraisal using the CASP criteria facilitated exploration of how each study could contribute to answering the review question. CASP highlighted that many papers (mainly position papers) achieved low quality scores on the Dixon-Woods criteria but could nonetheless offer valid and authoritative opinions.

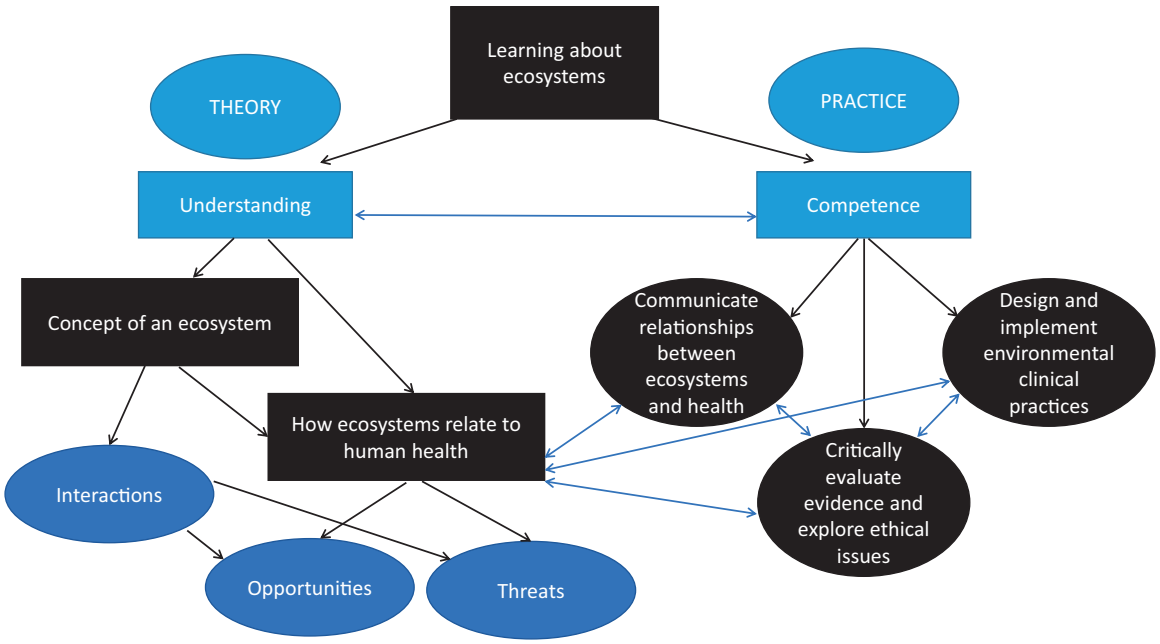

Figure 3. Conceptual map.

The quality of papers as assessed with CASP criteria is represented in Appendix S10 (published online as Supplementary Material) and discussed further in textual descriptions (see Appendix S6 published online as Supplementary Material) and the following paragraphs.

Exploration of the explanations given to support arguments

Agreement and disagreement between studies was explored further through reciprocal and refutational translation and examination of moderator variables.

Reciprocal and refutational translation

The focus of studies varies – from the impacts of ecosystem change on humans, to a more holistic perspective of ecosystems. Brazilian researchers note the 'predominance of the anthropocentric viewpoint' ('predominando o antropocentrismo'; Koerich et al. 2010, p. 3), which may focus on resources that humans take from ecosystems (e.g. energy resources (Su et al. 2011)) or threats that ecosystem change poses to human health (e.g. Bedsworth 2009; Worthington et al. 2010). Conversely, many studies are less anthropocentric and discuss ecosystems as units including human elements (e.g. Viero et al. 2012). While it is apparent that health professionals may need to learn about ecosystems links with human health, the reasons why health professionals may need to learn about aspects of ecosystems not related to health are less apparent and are not discussed in this literature.

Studies taking an anthropocentric view of ecosystems frame discussions around either health threats or opportunities for health promotion. Health threats include climate change (Bedsworth 2009; Pandve & Raut 2011), environmental change (Hollan et al. 1998) and pollution (Doerr-MacEwen & Haight 2006). Studies discuss the urgency of addressing humans' relationship with ecosystems to mitigate health threats (Hollan et al. 1998; AACN 2011). Opportunities for health promotion are less frequently mentioned, but include the health co-benefits of actions to protecting ecosystems (Charlesworth et al. 2012). Authors neither discuss the applicability, acceptability or usefulness of these contrasting anthropocentric/holistic and positive/negative perspectives, nor critique the lens through which their research or recommendations are framed.

Many studies measure participants' knowledge and awareness using questions that test knowledge (e.g. Villela et al. 2008) or by asking participants to rate their own knowledge (e.g. Bedsworth 2009). None of the measures used are validated. It is suggested that health professionals lack the knowledge required to inform others about environmental issues and enact environmental behaviours, e.g. correct waste separation (Corrêa et al. 2007) and energy-saving measures (Su et al. 2011). Studies in Cuba and Brazil suggest that educators have more knowledge about environmental problems than students (Cabrera & Tomey 2010; Viero et al. 2012); yet, some students demonstrate good understanding of anthropogenic environmental problems and their implications for health (Pandve & Raut 2011; Camponogara et al. 2012).

Findings suggest that students enjoy learning about ecosystems. The majority of health service workers undertaking a waste management course state that it was interesting (Takayanagui 1993) Nurses carrying out an educational action project were generally positive, but also expressed frustrations about slow pace of implementation (Laustsen 2005). Family-planning workers were interested in environmental health, but barriers to learning included time pressures and lack of

motivation (Worthington et al. 2010). Medical students and public health doctors are interested in environmental issues, but must be stimulated by educators (Charlesworth et al. 2012).

Moderator variables

Generally, limited information is provided about study population demographics, limiting the possibility of comparing results between and assessing the impact of variables such as age, ethnicity and setting.

Demographic and baseline characteristics of populations are often poorly described, especially in position papers (see Appendix S7, published online as Supplementary Material). Two position papers list signatories (Hollan et al. 1998; Medlin & Grupenhoff 2000), but other position papers do not describe the population endorsing the recommendations. Populations are usually described according to their profession, although often findings are aggregated so that data attributable to different professional or public groups are not identifiable. One study provides the views of scientists about health professional education (Blockstein & Mcmanus 2007). The only study that investigates the views of non-science professionals correlates with other results in suggesting that education to prevent over-prescription and wastage of medicines is needed and could be effective, but differs in identifying that other influences (such as marketing) may limit the feasibility of effecting change in practice (Doerr-MacEwen & Haight 2006). Involvement of individuals from outside the health sector may be a strength (providing perspectives from important stakeholders) and a weakness (stakeholders outside medical education may lack understanding about feasibility of strategies in medical education).

No association is seen between year of publication and type of study, study setting, population or results.

Study design may impact results about extent to which tomorrow's doctors already understand ecosystems–health links. Studies using multiple choice find that students have high levels of awareness and knowledge (e.g. Pandve & Raut 2011). Studies investigating understanding in more depth, especially using interviews, identify more deficits in understanding and knowledge (e.g. Viero et al. 2012).

Another moderator variable explored is setting. There is disproportionate representation of USA and Brazil (30% and 46% respectively of included studies). While the majority of studies (including all from Brazil) are qualitative, a disproportionately high number of the position papers (50%) are from USA. Interventional studies were carried out in clinical and non-clinical environments. Laustsen (2005), Takayanagui (1993) and Su et al. (2011) conducted action research, in US post-anaesthetic care, Brazilian hospital and pharmacy departments and Chinese hospital wards, respectively, all identifying positive impacts on knowledge and practice. Worthington et al. (2010) provided educational materials in a US family-planning centre with similarly positive outcomes. Charlesworth et al. (2012) and Fogarty et al. (2008) do not describe the setting of their studies, but infer that training was delivered in a non-clinical setting; and the impact on practice identified is more modest and more related to education than practice in the health care setting. Villela et al. (2008) and de Souza Bruzos et al. (2011) investigate interventions in medical schools, and no evidence of change in practice and only weak evidence of change in values and knowledge. In summary, interventions with clinicians in clinical settings found stronger evidence of impact on practice in health care settings.

Different methods are used to measure the effectiveness of interventions. Seven studies use questionnaires, five use semi-structured interviews and one study uses interviews, focus groups and participant observation. Tools that use open questioning identify unanticipated effects of environmental education, such as a sense of empowerment (Lausten 2005). A questionnaire study found medical students' had good knowledge of climate change (Pandve & Raut 2011), but a second questionnaire asked about more specific topics and highlighted deficits in students' knowledge (Cabrera & Tomey 2010). One reason for the discrepancy may be the design and conduct of the first questionnaire causing observer bias and only superficial evaluation of findings. Six studies identify positive change in participants' knowledge and/or awareness (Takayanagui 1993; Laustsen 2005; Villela et al. 2008; Worthington et al. 2010; Su et al. 2011; Charlesworth et al. 2012). Five research projects measure a change in individuals' behaviours following teaching about environmental issues (Takayanagui 1993; Laustsen 2005; Fogarty et al. 2008; Su et al. 2011; Charlesworth et al. 2012). Three projects identify impacts on organisational practices or outcomes: an action research project across one hospital identifies reduced spending on energy in a hospital following a programme of interventions (Su et al. 2011), field observation identifies improved waste management behaviours following another action research intervention with a small group of nurses (Laustsen 2005), and after delivery of a course about environmental sustainability, GPs reported that they improved organisational practice in their workplaces (Fogarty et al. 2008). One study suggests that the size of its impact is insignificant compared to the scale of the environmental problem (Fogarty et al. 2008). Only one study does not show any effect (positive or negative) of teaching (de Souza Bruzos et al. 2011). In this study, teaching is delivered to all students rather than a self-selected group and the outcome measure is self-reported knowledge.

Seven studies implement and evaluate an educational intervention; one retrospectively evaluates the effects of education about ecosystems. There is wide variation in teaching interventions; including format (online, on paper or face-to-face), topic (climate change to waste management), frequency (one standalone to weekly), and duration (one hour to many hours), which may account for the variation in results. Evaluation tools used include participant observation, focus groups, interviews and questionnaires; the majority of which are not validated or triangulated with other data.

Exploration of robustness

Contacting authors of all primary studies yielded suggestions of studies to review and comments on the product of synthesis.

Not all authors replied; no substantial comments were made on the product of synthesis, those that did agreed their study was correctly summarised.

Discussion

Reflection on rigour and robustness

This review was rigorous and transparent, informed by guidelines and guided by an expert panel. Nonetheless, a number of limitations are recognised, including lack of a clear definition and delimitation of the topic of ecosystems, lack of theoretical frameworks in this area, and the difficulty of identifying 'lack of need' for learning.

The only relevant model found after extensive literature searching was the Education for Sustainable Healthcare framework. In depth knowledge of this brings benefits as well as risk of over-interpretation or preference for the framework. This framework was not able to include all of the data identified in this review, but it accommodated much of the data, and helped to identify gaps relating to knowledge and understanding that tomorrow's doctors require. Thematic analysis of data that did not fall within the framework identified further themes arising from the data, thus enhancing the richness of the findings.

Sensitivity of searches is evidenced by the large number and range of publications identified. Non-English language papers were included, which offers an international perspective that is lacking in many reviews. However, even with professional translation, it is not possible to ensure that cultural references and subtleties of meanings are correctly understood. Translators were not available at all times during the analysis, therefore English language papers were more accessible for re-reading. Review of the product of synthesis by authors of non-English language studies improved the reliability of interpretation of their findings. Time limitations prevented systematic screening of reference lists of included papers being carried out, but brief screening of citations did identify one further paper for review. Identification of this paper (AACN 2011) highlighted that the databases did not include organisational reports[2], and lack of resources to carry out searching and documentary analysis of curriculum and organisational documents is recognised as a limitation of this review.

It was anticipated that there would be 'publication bias' towards arguments for the inclusion of this topic in medical education, because positive findings (i.e. supporting the inclusion of learning objectives) are more likely to be published (Ahmed et al. 2012). Within included studies, 'selection bias' is also a risk, because individuals who are interested in the topic area may be more likely to be recruited to studies (Winship & Mare 1992). Risk of 'identification bias' was minimised using broad inclusion and exclusion criteria in searching and screening. Abstraction followed extensive criteria that had been piloted by two researchers.

Careful record keeping, including recording of searches, protocols and references used improved transparency. Reporting was carried out and reviewed regularly throughout the research process. Experts from multiple disciplines were involved in regular review meetings. A reflective diary was used to elucidate factors that influenced the review process.

Reciprocal and refutational synthesis highlighted tensions between data, and exploration of moderator variables helped to highlight where quality of methods and reporting may have influenced results. Where multiple studies are of low quality they may confirm results, which are not dependable or generalisable to other settings or populations. For example, two studies identified an increase in participants' knowledge after an educational intervention, but both used repetition of the same questionnaire before and after the intervention and improvement may be due to learning from the process of completing the questionnaire rather than the intervention (Villela et al. 2008; Su et al. 2011).

Another limitation is the extent of available literature on this topic. Although a relatively large number of studies are included, it is few given the wide scope of the inclusion criteria. Furthermore, disproportionate representation of Brazil and USA is noted, which represents a limitation of the available data.

Findings

Tomorrow's doctors need to learn about ecosystems; this was a unanimous conclusion of all studies. Health professionals need to achieve both theoretical and practical learning about ecosystems. Included studies propose that health professionals should learn about key concepts, environment–health interactions and environmental impacts of health services; however, there is limited exploration of the depth and breadth of understanding required.

Analysis of quality finds that the majority provide clear aims within a suitable study design, but many have limited confirmability, with data collection, analysis and/or findings not clearly reported. Representational and inferential generalisability of findings is limited by small study populations and lack of reporting of the recruitment and characteristics of that population. Findings are, however, relatively consistent across the wide range of included studies.

The Education for Sustainable Healthcare Learning Objectives provided a useful framework for organising findings from the literature about what tomorrow's doctors need to learn. The literature suggests that they should have some understanding in all three key learning areas, although more evidence relates to the first two areas:

Relationships between ecosystems, environmental change and human health

Many studies suggest that health professionals should understand the links between ecosystems and human health, including how environmental change affects health and how human activities can degrade or protect the environment.

[2]The AACN (2011) report was identified in the reference list of a paper that was identified through database searching and subsequently excluded because all of its relevant findings were references from the AACN report (Schenk et al. 2012).

In keeping with the framework, studies suggest that health professionals should have knowledge of environmental threats to health, including air pollution, environmental toxins and climate change. Opportunities for health promotion arising from an understanding of ecosystems are mentioned, but with less frequency and weight than threats relating to ecosystems. Only one study discusses the 'co-benefits' of healthy and environmentally sustainable behaviours (Charlesworth et al. 2012). This may reflect the relative readiness of health professionals to fulfil roles treating ill health rather than preventing harm (through health promotion), which reflects findings about the views of practising physicians (Steptoe et al. 1999).

While the Education for Sustainable Healthcare framework is focused on implications of environmental change for humans, studies in this review suggest that health professionals should also learn about the concept and value of ecosystems. The latter is a more ambitious target for medical education, and whether this is within the remit of medical education requires further exploration.

Relationships between health systems and ecosystems

Many studies suggest that health professionals should learn about the environmental sustainability of health services, but none explores the range of required knowledge, attitudes or skills in this area. Studies suggest that consciousness and understanding of ecosystems can motivate and inform environmental actions. Similarly involvement in environmental projects can be a route to learning; not only affecting the involved and interested group, but also increasing awareness and behaviour of the wider population of health professionals. This is supported by educational theory, which suggests that direct experiences of an issue or practice, as opposed to learning about related theory, have a stronger influence on practice (Kollmuss & Agyeman 2002) and professionalism (Passi et al. 2010).

Specific competencies for health professionals proposed include communicating environmental issues to the public and contributing to environmentally sustainable management and delivery of health care services. No study specifically recommends learning about measurement of the ecological footprint of health services, but the term 'environmental stewardship' suggests being able to both measure and manage resource use and emissions. It is also recommended that medical educators learn about the environmental sustainability of health professional education. The evidence suggests that focused education on waste management, travel planning, water usage and energy efficiency can result in cost and environmental savings in the health service.

Improving the environmental sustainability of health services is identified as a goal that can be furthered through education about ecosystems. Qualitative research suggests health professionals need education to enact environmental practices. Intervention studies indicate an increase in knowledge about ecosystems and action to improve protect ecosystems following education of health care workers. Participants responded positively to interventions and small improvements in practice were seen, however the impacts are modest and generalisability from small self-selected groups to students and doctors in general is not explored.

Professionalism, ethics and the law in relation to ecosystems and health

Studies included in this review suggest that future health professionals should develop critical thinking, which suggests a need to think reflexively about problems and responses. A minority of papers suggested that health professionals need to know about health equity and environmental laws. There is limited discussion of specific issues such as resource distribution (not specifically mentioned), health equity (mentioned in one study only) and environmental laws (mentioned in two studies). No studies explicitly discuss the relationship between ecosystems thinking and the duties of a doctor, but some suggest that knowledge and understanding about the need to protect ecosystems is an important aspect of citizenship or professionalism. The wider literature supports the role of education about ecosystems in developing professionalism and promoting ecological behaviours (UNESCO 2013).

The breadth of the evidence

Justifications were given for learning about ecosystems. Intervention studies provided weak evidence, supporting the opinions that education about ecosystems can achieve participation, increasing knowledge and understanding, promote environmental behaviours and even improve organisational practices or outcomes.

Evidence is drawn from a diversity of research perspectives, study designs, populations and geographical locations. There is insufficient evidence to draw strong conclusions in any specific group or setting. Nonetheless, findings can be correlated across studies and provide theories that may contribute to the evidence base.

No studies included in this review explore the extent of knowledge, understanding and competence that is required. A lack of evidence about specific content to include in medical education may exist because this is a relatively new perspective for medical educationalists. Researchers and authors may have limited knowledge and awareness of the rapidly evolving science of ecosystems and human health and lack confidence to research detailed aspects of the topic or provide specific recommendations. The limited data on topics in environmental education are consistent with findings from other disciplines showing that most research focuses on the ecological footprint of educational institutes not environmental education (UNESCO 2013).

Recommendations

From these findings, we recommend that:

- medical curricula include theoretical understanding and practical capabilities relating to ecosystems. Tomorrow's doctors require not only understanding of the concept of ecosystems and its relationship to health, but also competence to enact appropriate behaviours and actions, such as measuring and managing the ecological footprint of health care and communicating about ecosystems and

health. This should be reflected in local and national curricula and supported by professional bodies and educational leaders.
- research in the local context investigates the extent to which tomorrow's doctors already understand relationships between ecosystems and health, and are confident to enact sustainable behaviours.
- education be tailored to local priorities and needs, informed by discussion with students and other stakeholders in medical education and evaluation of existing teaching.
- the Education for Sustainable Healthcare framework be developed to include practical competencies, and interpreted locally according to needs of trainees.
- research explores how education of different health professional groups are equivalent or different, to enable translation of findings from one health professional group or setting to another.
- research and evaluation explore effective pedagogies for teaching about ecosystems.

Conclusions

This systematic review synthesises perspectives from the international peer-reviewed and grey literature about the relevance of ecosystems to medical education. The review identifies a thin but broad evidence base spanning many settings and research perspectives. Although there is limited research about this topic, many high level opinions (statements from expert consensus and professional bodies) were identified.

The evidence suggests health professionals perceive that they have learning needs relating to ecosystems. Stakeholders both within and outside of health professions support the view that tomorrow's doctors need to understand the relationship between environment and health and be able to put sustainable practices into action. The Education for Sustainable Healthcare framework proved highly relevant but could be strengthened by tailoring to different health professional groups and addition of practical competencies.

Notes on contributors

SARAH WALPOLE, BSc, MBChB, MRCP, MSc (Res), is a Medical Registrar and Research Lead at the Sustainable Healthcare Education Network.

DAVID PEARSON , FRCGP, FHEA, EdD, is a GP in Bridlington, Yorkshire, UK.

JONATHAN COAD, BMedSc, is a Core Medical Trainee at Southampton.

STEFI BARNA, MPH, is a Lecturer in Global Public Health.

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