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# A HIDDEN GAP: LACK OF PUBLISHED EVIDENCE ON SUCCESSFUL ONE HEALTH CURRICULA DEVELOPMENT, IMPLEMENTATION, AND OUTCOMES IN MEDICAL EDUCATION

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## ABSTRACT

*Background and objectives*: For decades, there have been many opinion and perspective publications advocating to include One Health in medical curricula. However, it is also known that there are numerous barriers for doing so including a lack of expertise and difficulty of transdisciplinary collaborations, both of which are essential for the development of One Health curricular

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content. This study comprehensively reviews peer-reviewed publications on One Health curricula in undergraduate medical education, with a focus on the curricular content in terms of scope and substance, implementation strategies, and outcome assessments.
*Methods*: A comprehensive PubMed search was conducted to identify articles that addressed the integration of One Health into undergraduate medical curricula. Eligible articles were screened and categorized based on their primary focus: (1) scope and substance of One Health topic coverage, (2) incorporation of transdisciplinary collaboration, (3) teaching and learning strategies, and (4) outcome evaluation or assessment.
*Results*: A total of 3,445 publications in peer-reviewed journals over a span of 40 years (1983 to 2023) were screened, and only three met the inclusion criteria for detailed analysis. Most publications focused on conceptual advocacy or general descriptions of educational processes, with few offering concrete curricular materials or educational outcome evaluations.
*Conclusion*: This review highlights a hidden gap in peer-reviewed, published literature: a scarcity of tangible, peer-reviewed examples of One Health curricular materials developed and evaluated for undergraduate medical education. Therefore, to support the integration of One Health into physician training across institutions, we urge One Health educators and journal editors to prioritize the dissemination of practical course materials, implementation guides, and evidence-based outcome data. This is essential to prepare future physicians to address complex global health challenges through a One Health lens.

**Keywords:** one health education, medical curriculum, one health curriculum development, one health curriculum assessment

## INTRODUCTION

Pandemics have punctuated human history, with the 1918–1919 “Spanish flu” marking a pivotal turning point in modern public health. Since then, seven additional pandemics have occurred, including the most recent COVID-19 started by the SARS-CoV-2 virus, which emerged in late 2019 (Piret and Boivin, 2021). Time and again, both healthcare professionals and the public are inadequately prepared to confront emerging health threats. The COVID-19 pandemic vividly illustrates how the sudden emergence of a novel virus can rapidly result in a global crisis, severely affecting human health, overwhelming healthcare systems, and disrupting nearly every aspect of society (Bartik et al., 2020; Mishra et al., 2020; Isasi et al., 2021). This occurred despite longstanding warnings from public health experts about the growing threat of emerging and re-emerging infectious diseases (Zinsstag et al., 2018; Kobayashi, 2018). Therefore, it once again underscores the urgent need to equip future healthcare professionals with the knowledge and competencies necessary for effective

pandemic preparedness, including surveillance, prevention, early detection, and coordinated response.

The concept of One Health represents a fundamental shift in how we address the complex and myriads of health challenges associated with modern human activities, especially in the context of changing animal-human interface (Allen-Scott et al., 2015; Destoumieux-Garzón et al., 2017). Specifically, One Health emphasizes the interdependence of human, animal, and environmental health: many animals serve as reservoirs for pathogens that affect humans, and environmental disruptions can bring animals and humans closer, causing disease emergence across species. One Health advocates for a comprehensive, transdisciplinary approach that engages stakeholders across education, research, public health, industry, utilization of natural resources, and government at all levels to protect human health, animal health, and sustainable ecosystems (Allen-Scott et al., 2015; Destoumieux-Garzón et al., 2017). A recent review of evidence shows that One Health strategies are particularly effective for early detection, surveillance, and control of endemic and neglected diseases (Zinsstag et al., 2023). Accordingly, integrating One Health into medical education is critical to preparing physicians to recognize, prevent, respond to, and manage emerging threats.

Since the 1990s, global health authorities, including the World Health Organization, have cautioned against an impending crisis of infectious disease, emphasizing that no nation is immune to its threat (World Health Organization, 2017). However, a recent review of One Health research has found that somehow identifying zoonotic pathogens and their transmission dynamics has been prioritized unintentionally (Miao et al., 2022). Interestingly, despite these developments, medical education has largely maintained a reactive stance toward zoonotic diseases, focusing primarily on human pathophysiology, vectors, risk factors, clinical presentation, diagnostic methods, and treatment of already recognized conditions, while neglecting the ecological and environmental contexts from which these diseases reemerge, or new diseases emerge (Rabinowitz et al., 2017; Lewis et al., 2020; Dykstra and Baitchman, 2021). This narrow focus leads to a fragmented understanding of the evolutions of pathogens and the mechanism by which they jump over to humans, leaving future physicians ill-equipped to address health threats shaped by various One Health determinants including but not limited to animal-human interface, biodiversity loss, and global mobility. Therefore, it is essential for educators to move beyond traditional approaches to infectious disease education and embrace the integrated perspective of the One Health framework (Sikkema and Koopmans, 2021; Ghai et al., 2022; Hayman et al., 2023; Singh et al., 2024), which emphasizes for the incorporation of ecological risk assessment, climate change, animal-human interactions, sustainable practice, strong transdisciplinary collaboration, and early warning systems into medical training.

The goal of One Health education in the medical curriculum is to prepare physicians globally to contribute to disease surveillance, identification of pre-emergent threats, and development of strategies and policies to manage both clinical and public health consequences of novel pathogens (Allen, 2015; Frankson et al., 2016). This includes preparing for "Disease X," the placeholder term adopted by the WHO to denote a future disease caused by a as yet unknown pathogen with pandemic potential (World Health Organization, 2017).

The urgency to embed One Health into medical education globally has grown over the past two decades, marked by outbreaks of West Nile virus, SARS, H1N1, MERS, Zika, Ebola, and Mpox (Bhadoria et al., 2021). Many of these outbreaks were linked to ecological disruptions and/or climate changes that caused increased animal-human interface activities (Lloyd-Smith et al., 2009; Reperant and Osterhaus, 2013; Ruwini et al., 2022). Ongoing surveys have identified widespread distribution of animal reservoirs with epidemic potential (Han et al., 2015; Wong et al., 2019; Rahman et al., 2021; He et al., 2022). More recently, avian influenza H5N1 has been detected in wild birds, cattle, and household pets (Chen et al., 2022; Naraharisetti et al., 2024; Szaluś-Jordanow et al., 2024; Nguyen et al., 2025), and more concerningly, H5N1 has sporadically spilled over to humans over a long period of time (Lai et al., 2016; Moncla et al., 2020; Castillo et al., 2023; Garg et al., 2025). These findings illustrate the increasing frequency and complexity of disease emergence and again the urgent need to prepare future physicians accordingly.

Importantly, the relevance of One Health extends beyond zoonotic infectious diseases. Pressing global issues such as antimicrobial resistance (Robinson et al., 2016; Fang et al., 2024; Hu et al., 2024), food safety and security (Lowe, 2021; Lahti et al., 2023), agriculture practices and wildlife habitat loss (Paulson et al., 2015; Jones et al., 2020; Nguyen et al., 2022; Eby et al., 2023), and exposure to environmental toxin (Buttke, 20211; Brack et al., 2022; Chen et al., 2024; Wang et al., 2024), all demand integrative thinking and research under the One Health concept. Yet, a recent bibliometric analysis reveals a disproportionate focus on zoonotic pathogens, with limited research on other domains, and a dominance of natural science disciplines over social, environmental, or policy-oriented fields (Miao et al., 2022). This imbalance raises important questions about whether the educational development of One Health curricula reflects similarly narrow priorities.

To ensure the quality and comprehensiveness of One Health curricular content for medical students, its development must be co-created through collaboration among experts from diverse fields, including medicine, veterinary science, public health, ecology, environmental science, and social sciences, to name a few, and should highlight the interconnectedness of human, animal, and environmental health (Allen-Scott et al., 2015; Destoumieux-Garzón et al., 2018; Zingsstag et al., 2023). The curricular content must be supported by established scientific evidence, and it should be adaptable to varied regional

and local contexts. In addition, the content should incorporate strategies, solutions, and ongoing research related to surveillance, risk mitigation, and environmental interventions. Emphasis should be placed on preparing students to proactively anticipate and prevent health threats, rather than responding only at the point of care, which may be insufficient as illustrated during the early days of the COVID-19 pandemic. The curriculum should also encourage students to consider the environmental impact of clinical practices and to promote sustainability in healthcare. Ultimately, students should be educated to be ethical stewards of planetary health.

Effective One Health education differs from traditional disciplinary approaches by relying on transdisciplinary collaboration among experts from diverse fields, many of which are not typically represented in medical school curricula. These include veterinary science, agricultural science, climatology, ecological health, and social sciences. This challenge is further compounded by the fact that academic institutions are often structured into disciplinary silos, each with distinct vision and mission, operational goals and research priorities that can impede meaningful transdisciplinary collaboration (Destoumieux-Garzón et al., 2018; Johnson et al., 2018; Yopa et al., 2023). Addressing these structural barriers is essential for developing robust, integrated, and sustainable One Health curricula in medical education.

Several specific obstacles to interdisciplinary integration in medical education have been identified. First, institutional silos lead to the separation of human, veterinary, and environmental health education, limiting students' exposure to cross-disciplinary collaboration (Cai et al., 2024). Second, curriculum overload and competing academic priorities, such as pharmacology versus anatomy, often hinder the inclusion of new content, even when its relevance is acknowledged (Rabinowitz et al., 2017; Docherty and Foley, 2021; Tucker et al., 2024). Third, a lack of faculty expertise in One Health presents a major challenge to effectively teaching and integrating its core principles (Cai et al., 2024). Fourth, a lack of resources, particularly in low- and middle-income countries, often results in the unavailability of high-quality interdisciplinary programs, making it difficult to implement comprehensive One Health education (Cai et al., 2024). Fifth, inadequate institutional policy support and funding continue to obstruct the development and implementation of comprehensive One Health curricula (Rabinowitz et al., 2017; Docherty and Foley, 2021; Yopa et al., 2023; Cai et al., 2024; Tucker et al., 2024). Finally, the politicization of the COVID-19 pandemic response has made it increasingly difficult to teach the ecological drivers of disease emergence in an objective, evidence-based manner (Kerr et al., 2021; Stroebe et al., 2021; Bolsen and Palm, 2022).

The COVID-19 pandemic exposed a critical gap in medical education – that is, the medical curriculum had not addressed the complex interplay of biological, environmental, and human health on a global scale. But the pandemic sparked a surge in commentary on the urgency of One Health

education in medical schools (Dykstra and Baitchman, 2021; Frenk et al., 2022; Zyoud, 2024), creating a valuable opportunity to advance this approach and better equip physicians for future challenges. The question of how to meaningfully integrate One Health into medical education is not merely a theoretical concern, but rather a practical imperative. As human activities continue to disrupt ecosystems, accelerate climate change, and expand the animal–human interface, the relevance of the One Health approach will only grow. A 2020 survey of 133 U.S. medical schools reported that 56% included One Health–related content in preclinical classroom learning (Docherty and Foley, 2021). However, the scope and substance of this content, the approaches used for implementation, the ways in which students engage with the material, and the outcomes by which it is assessed all need to be systematically evaluated. This is important because without systematic curricular development and evaluation, the ability of future physicians to apply One Health principles in emerging health crises cannot be assured. Equally important is the dissemination of curricular content, implementation strategies, and assessment outcomes through peer-reviewed publications, as this can support improved education and promote greater standardization globally.

More than five years after the emergence of SARS-CoV-2 and the COVID-19 pandemic, the time is ripe for a systematic examination of how medical education has advanced the integration of One Health principles. In this review, we examined the published literature to investigate how and to what extent One Health content, both in scope and substance, has been included in undergraduate medical education. We also explored how One Health has been implemented, as well as the frameworks and best practices guiding this process. Specifically, we focused on three core dimensions: curriculum content development, mechanisms of curriculum implementation, and assessment outcomes. By examining these dimensions, we aimed to provide a comprehensive understanding of the types of One Health educational materials that have been developed, implemented, and evaluated in medical schools, and to identify opportunities for improvement and innovation.

## METHODS

### *LITERATURE SEARCH STRATEGY*

A comprehensive literature search was conducted using PubMed to identify relevant studies. The search included combinations of terms such as “One Health,” “Planetary Health,” and “Sustainability” paired with “Curriculum,” “Student,” and “Medical School” to ensure broad coverage. The exact search string used was: (“One Health” OR “Planetary Health” OR “Sustainability”) AND (“Curriculum” OR “Student” OR “Medical School”). The search was completed on December 9, 2023. The search identified 3445 publications since February 1983.

***Inclusion and exclusion criteria:*** Only articles published in English were included, as the research team was not proficient in other languages and lacked financial resources to pay for language translation services. Articles were eligible for inclusion if they addressed One Health or global health themes, focused on undergraduate medical education, and discussed curriculum content development, implementation or instructional strategies, or the assessment of educational outcomes. Commentaries, editorials, and opinion pieces without empirical or descriptive data were excluded.

## *SCREENING AND REVIEWING PROCESSES*

All articles identified in the initial search through PubMed were exported to an Excel® spreadsheet and duplicates were removed. Titles and abstracts of the remaining articles were screened independently by reviewers using a divide-and-conquer approach, in which each team member was assigned a specific

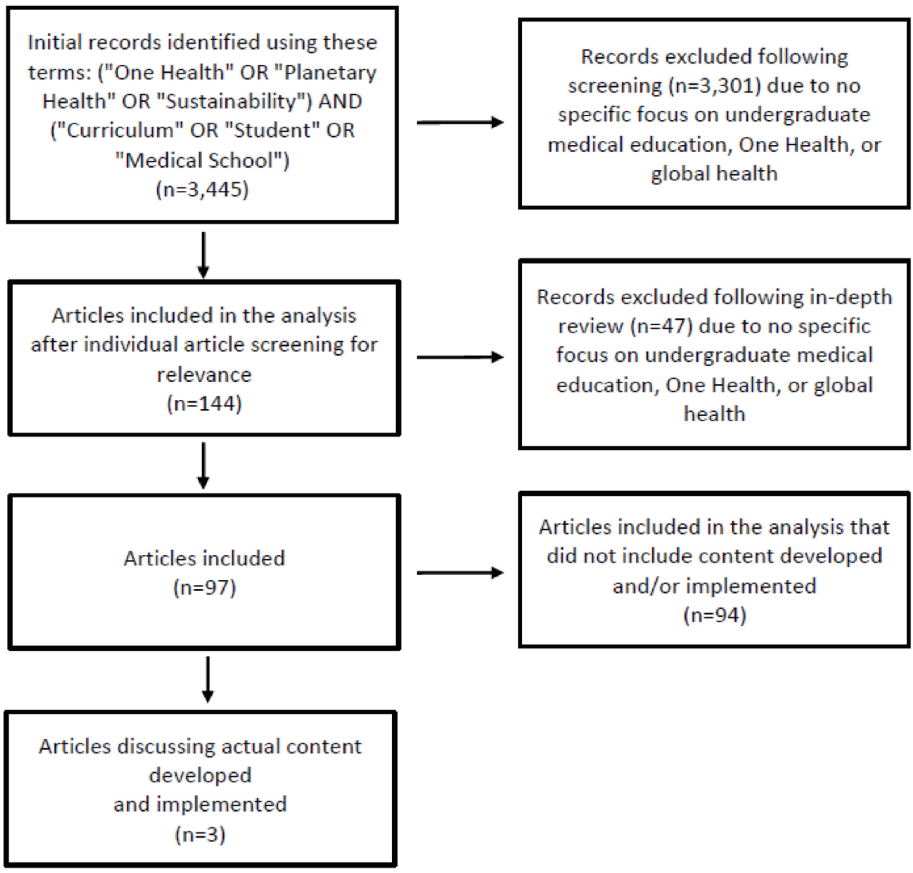


**Figure 1. Literature review flowchart**

subset of articles to assess for relevance based on the pre-specified inclusion and exclusion criteria. A total of 144 articles were deemed relevant underwent full-text review.

## RESULTS

Figure 1 presents the flowchart of the study selection process. Our search identified 3,445 records published from 1983 to 2023. All were screened according to predefined inclusion criteria: articles had to address either One Health or global health and be relevant to undergraduate medical education. Most exclusions were due to a lack of relevance to undergraduate medical education. This screening yielded 144 articles for full-text review.

To assess whether each article was relevant to the development of One Health content in medical curricula, we assessed them based on four thematic areas (Table 1). Most articles did not provide details on specific content developed. For example, 41% were opinion pieces advocating for One Health education in medical schools, and while 45% outlined general guidelines for content development in undergraduate medical education.

Only three articles described both the specific content developed, implemented and outcome assessment (Tables 2 and 3).

Of the three articles, one presented a two-week One Health elective that included a broad range of topics (Docherty and Foley, 2021). The other two focused on case-based learning related to environmental health: one described a case of diarrhea linked to contaminated water, and the other addressed asthma exacerbated by wildfire smoke (Ramkumar et al., 2021; Park et al., 2023). Details of the curricular content from these three articles are provided in Tables 2 and 3.

**Table 1. One health curricular content areas reviewed**

| Content Area | Key Considerations for Content Development |
|---|---|
| Comprehensiveness of Coverage | • Include humans, animals, and environmental health.<br>• Convey One Health principles and practices comprehensively.<br>• Address social, economic, and environmental health determinants. |
| Transdisciplinary Collaboration | • Integrate concepts from diverse fields such as medicine, veterinary medicine, ecology, environmental science, public health, economics, and social sciences.<br>• Promote interdisciplinary learning and collaborative problem-solving. |
| Engagement and Interactivity | • Incorporate case studies, simulations, and gamified activities.<br>• Encourage active learning and critical thinking. |
| Outcome Evaluation and Assessment | • Assess effectiveness in achieving learning outcomes.<br>• Implement feedback mechanisms for ongoing improvement. |

**Table 2. A two-week one health elective developed and implemented at Georgetown University School of Medicine, Washington, DC, USA**

| Elective Description, Implementation, and Assessment | Delivery Format, Specific Content Covered and Aims of the Elective | Ref. |
|---|---|---|
| **Involvement of Transdisciplinary Expertise:**<br>Information not available<br>**Content development:**<br>• A two-week long elective, entitled "One Health: Exploring the Interplay of the Health of People, Animals and the Environment in Global Health Threats"<br>• Content is organized around four key categories: 1) Exploring the interdependency of the health of people, animals and the environment; 2) Understanding the value and challenges of using a OH approach in dealing with complex public health problems; 3) Recognizing the role and responsibilities of stakeholders involved during a zoonotic disease outbreak; and 4) Understanding the importance of coordination and communications across sectors (e.g., animals, humans and environment) and agency levels following detection of an outbreak.<br>**Implementation:**<br>• The elective was offered in 2020 to 21 third-year medical students on-line due to the COVID-19 pandemic.<br>**Assessment:**<br>• Before starting the elective, students were asked to complete an on-line surveyed with 16 questions (multiple choice or open-ended response questions) divided into demographic questions and knowledge and rating of importance of One Health.<br>• After completion of the elective, the students were also surveyed with 13 questions divided into rating importance of OH and evaluation of the course. Most questions asked students to provide feedback on the elective.<br>**Assessment outcome:**<br>Before the elective, 27% of students had no knowledge of One Health.<br>Before the elective, 36% of students considered incorporating One Health activities into medical school curricula as very important compared to 85% of the students afterwards.<br>Before the elective, 45% of students agreed that One Health training is relevant to their future career as a medical professional compared to 75% afterwards. | **Guest lectures and discussions**<br>• Overview of one health<br>• Using earth observations to strengthen one health collaborations<br>• One Health and Catholic social doctrine<br>• Vector ecology<br>• Mosquito disease transmission and emerging infectious diseases<br>• Tick-borne diseases<br>**Case study**<br>• Pet-associated Campylobacteriosis<br>**Current events student presentations**<br>• A range of One Health related topics chosen by the students<br>**Simulation exercise including pre-recorded lecture, live presentation, small group discussion, and memo assignment**<br>• Simulation exercise designed to highlight critical health care and public health interface in the context of an infectious disease emergency.<br>• Principles of public health emergency preparedness and healthcare crisis standards of care.<br>• Fictional Influenza outbreak.<br>• How to prepare for an emergency planning meeting<br>**Virtual Zoo Tour**<br>• Virtual tour of local zoo veterinary care facilities<br>• One Health from a zoological vet's perspective<br>• Application of Operant training in zoological medicine<br>• Considerations of practical clinical comparative nutrition<br>• Comparative mammalian anesthesia and anesthetic techniques<br>**One health immersion experiences**<br>• Climate change and the practicing Clinician<br>• Discuss experiences with Health in Harmony ASRI Clinic in Indonesian Borneo<br>**Aims**<br>• Exploring the interdependency of the health of people, animals, and the environment.<br>• Understanding the value and challenges of using a OH approach in dealing with complex public health problems.<br>• Recognizing the role and responsibilities of stakeholders involved during a zoonotic disease outbreak.<br>• Understanding the importance of coordination and communications across sectors (e.g., animals, humans, and environment) and agency levels following detection of an outbreak. | Docherty & Foley, 2021 |

Table 2 provides a detailed overview of a two-week One Health elective developed and implemented at Georgetown University School of Medicine in Washington, DC, USA (Docherty and Foley, 2021). The course, titled "One Health: Exploring the Interplay of the Health of People, Animals and the Environment in Global Health Threats," was offered online in 2020 due to the COVID-19 pandemic and enrolled 21 third-year medical students. The elective was structured around four major themes: (1) understanding the interdependency among human, animal, and environmental health; (2) evaluating the value and challenges of a One Health approach in managing complex public health issues; (3) identifying stakeholder roles and responsibilities in zoonotic disease outbreaks; and (4) emphasizing the need for coordination and communication across human, animal, and environmental health sectors during public health emergencies.

The delivery format of the elective was highly interactive and varied, including guest lectures, case studies, simulation exercises, and virtual experiences. Guest lectures covered diverse topics such as vector ecology, zoonotic disease transmission, and the intersection of One Health with Catholic social doctrine. A notable simulation exercise engaged students in a fictional influenza outbreak scenario, teaching principles of public health emergency preparedness and healthcare crisis standards of care. Additional experiential learning components included a virtual tour of zoo veterinary facilities and discussions with practitioners from the Health in Harmony ASRI Clinic in Indonesian Borneo. Students also explored themes like comparative mammalian anesthesia, clinical nutrition, and climate change impacts on clinical practice.

Assessment of the elective included pre- and post-course surveys. Prior to taking the elective, 27% of students reported no prior knowledge of One Health. Only 36% considered One Health activities very important in medical education, and 45% believed their training was relevant to their future careers. After the elective, these figures rose significantly: 85% viewed One Health as very important for medical curricula, and 75% acknowledged its relevance to their future medical practice. This indicates a substantial positive shift in student perceptions following the program, supporting its effectiveness in promoting One Health literacy among future physicians.

In Table 3 we summarize two educational case studies (Ramkumar et al., 2021; Park et al., 2023) developed at the University of Illinois Colleges of Medicine at Urbana, showcasing how One Health and climate change concepts are integrated into medical education through interdisciplinary and simulation-based teaching.

Case 1: "Asthma Exacerbation Triggered by Wildfire – A Standardized Patient Case" - This second case involved a standardized patient (SP) scenario focusing on a female patient experiencing worsening asthma due to exposure to distant wildfire smoke (Ramkumar et al., 2021). Developed by faculty in the Department of Medicine, the case was integrated into an Objective Structured

**Table 3. Cases developed by faculty members at the University of Illinois Colleges of Medicine at Urbana, IL**

| Involvement of Transdisciplinary Expertise | Case Description and Educational Aims | Method of Delivery and Assessment | Ref. |
|---|---|---|---|
| Members collaborated to develop this case are from the following departments:<br>• Department of Biomedical and Translational Sciences, College of Medicine.<br>• Department of Clinical Sciences, College of Medicine<br>• Department of Veterinary Clinical Medicine, College of Veterinary Medicine<br>• Department of Kinesiology and Community Health, College of Applied Health Sciences<br>• Champaign-Urbana Public Health District | **Case 1 and title:**<br>Beyond the Imodium, a One Health discussion on diarrhea and the impact of climate change<br><br>**Case:**<br>This is a scenario that concerns a diarrhea outbreak due to a contaminated water supply from a manure lagoon precipitated by extreme flooding in a rural community. It used the One Health framework to highlight the impact of climate change and extreme weather events.<br><br>**Aims:**<br>Bring students from each discipline to share their expertise and learn about health risks; Promote awareness of the impact of climate change-driven extreme weather events on human and animal health. | **Method of delivery:**<br>The case was explored over two virtual sessions, each lasting 90 minutes. Students were placed into small, interdisciplinary breakout groups led by faculty from the three participating colleges. Each group was intentionally structured to include students from all three disciplines, with a maximum of ten participants per group. Faculty facilitators used a discussion guide they had co-developed, prompting students with questions tied to the evolving case scenario. To support discussion, students were given background readings in advance. The case itself was presented through a series of PowerPoint slides that incorporated images, dialogue, and short video clips featuring central figures such as a farmer, a physician, a veterinarian, and a public health professional. After small group discussions, all participants rejoined the main session to share insights and proposed strategies for addressing the challenges raised in the case.<br><br>**Assessment:**<br>Students were asked to evaluate their awareness of five factors related to the case study before and after participating in the discussion. This was achieved based on their answers to the five questions below:<br>1. How aware were/are you of the infectious causes and risk factors that contribute to diarrhea in human and animal outbreaks?<br>2. How aware were/are you about public health initiatives for mitigation of contaminated water sources?<br>3. How aware were/are you of consequences of flooding due to extreme weather on animal, human and community health?<br>4. How aware were/are you of strategies to build resilience against future climate threats?<br>5. How aware were/are you of the interprofessional nature of this type of case?<br><br>**Key assessment findings:**<br>• There was a statistically significant increase in awareness across all questions after the exercise when compared to before the exercise.<br>• The largest increase was in awareness of the interprofessional nature of the exercise, suggesting successful engagement of students in an interdisciplinary manner.<br>• 96% of respondents said they were interested in more One Health case activities in the future. | Park et al, 2023 |

*(Continued)*

**Table 3. (Continued)**

| Involvement of Transdisciplinary Expertise | Case Description and Educational Aims | Method of Delivery and Assessment | Ref. |
|---|---|---|---|
| Members collaborated to develop this case are from the Department of Medicine, University of Illinois Colleges of Medicine at Urbana, IL. | **Case 2 and title:**<br>Asthma exacerbation triggered by wildfire: a standardized patient case to integrate climate change into medical curriculum through simulation.<br><br>**Case:**<br>The case depicts a retired female with asthma, and she is suffering from worsening asthma symptoms related to distance wildfires. The case contained historical backstory with details of the patient's risk due to exposure to wildfire smoke as well as the impacts on her lifestyle and overall mental and physical health.<br>This case is used in as part of a standard OSCE already included in the curriculum. It is used to challenge students to develop a treatment plan and recommendations which include addressing environmental exposures and vulnerabilities.<br>**Aims:**<br>The aim is to increase awareness, knowledge, and skills related to the connection between climate change and health, as well as strategies for mitigation and adaptation. Specific case objectives are:<br>• Obtain a focused history relevant to the chief complaint<br>• Identify environmental health risks and vulnerabilities<br>• Perform a focused physical exam<br>• Develop a differential diagnosis and/or problem list<br>• Develop a treatment plan and recommendations which include addressing environmental exposures and vulnerabilities<br>• Synthesize clinical data in a structured note | **Method of delivery:**<br>Third-year medical students, midway through their internal medicine clerkship, participated in Objective Structured Clinical Examination (OSCE). As part of routine preparation, students received logistical details and instructional materials via email two weeks prior. They were also informed that one of the standardized patient (SP) encounters would focus on the intersection of climate-related health risks and a common clinical condition. Preparatory resources included a TED Talk video and reading materials to help frame this context.<br>Faculty involved in the OSCE were provided with detailed support materials in advance, including checklists for history-taking and physical examination, an exemplary clinical note, and a structured debriefing guide. These resources included criteria for asthma diagnosis and specific information on climate-related adaptation and mitigation strategies. Faculty were also encouraged to highlight the psychosocial dimensions of the patient's illness, particularly in relation to environmental stressors like wildfires.<br>The OSCE included two formats: a group encounter and a one-on-one encounter.<br>In the **group format**, five students interacted with a single SP under the supervision of two internal medicine faculty members. Students rotated roles in conducting the interview and physical examination, and each then presented their diagnostic impressions and management plans. The SP provided direct feedback on students' communication skills. A group debrief followed, led by faculty, who reviewed key clinical findings, addressed the patient's vulnerabilities—particularly the link between asthma exacerbation and wildfire exposure—and facilitated discussion on climate-related health risks, mental health concerns, and social determinants such as financial constraints and caregiving dependence. The session also included strategies for individual patient management, climate adaptation, and mitigation.<br>The **one-on-one format** involved five students, an oral maxillofacial surgery resident, two SPs, a simulation coordinator, and two internal medicine faculty members. Each student conducted a solo encounter with an SP, including history-taking, focused physical examination, diagnostic reasoning, and patient counseling. Students then documented their findings in a structured clinical note. Throughout the session, faculty observed via video and later held individual debriefings to review student performance. Written notes were evaluated against an exemplar, and faculty emphasized connections between environmental factors and clinical outcomes—mirroring the thematic content of the group sessions. SPs also provided individualized verbal feedback on communication skills.<br><br>**Assessment:**<br>• Evaluate basic clinical and communication skills inherent in any OSCE format<br>• Evaluate the effectiveness of the educational strategy to increase medical students' knowledge, skills, and awareness of health impacts of climate change.<br><br>**Key assessment findings**:<br>• Students recognized that the information they gathered from medical history helped them focus on exposures and risks and recognize the health impacts of climate change.<br>• Students demonstrated awareness of the importance of being climate-aware providers who could include patient education in their management plans.<br>• Students expressed appreciation of the exercise. | Ramkumar, et al. 2021 |

Clinical Examination (OSCE) for third-year medical students during their internal medicine clerkship. It highlighted the connection between environmental exposures and clinical conditions, while also addressing mental health and social vulnerability.

Students received preparatory materials, including a TED Talk video and readings on climate change and health. The OSCE was delivered in two formats: a group encounter and an individual one-on-one session. In the group setting, five students interacted with an SP under faculty supervision, rotating roles in the interview and exam while later presenting their diagnostic and treatment plans. Faculty-led debriefs explored asthma management, environmental risk mitigation, and climate-related vulnerabilities. In the individual format, each student conducted a full SP encounter observed via video by faculty, followed by feedback and evaluation of their written clinical notes. Emphasis was placed on linking environmental exposures to patient care and communication.

Assessment outcomes indicated that students were able to effectively link clinical history with environmental health risks, recognize the significance of the climate–health relationship, and consider healthcare within a specific contextual framework. They valued the simulation's relevance and appreciated the integration of climate-related patient education into clinical decision-making.

Together, these two cases represent effective models for incorporating One Health and climate change into the medical curriculum through transdisciplinary collaboration, simulation, and reflective learning.

Case 2: "Beyond the Imodium – A One Health Discussion on Diarrhea and Climate Change" – This case study was developed by a transdisciplinary team and focused on a diarrhea outbreak in a rural community caused by water contamination from a manure lagoon following extreme flooding (Park et al., 2023). It was designed to highlight the interconnections among human, animal, and environmental health, using the One Health framework to illustrate the impacts of climate change and extreme weather events. Faculty collaborators from five different disciplines - including medicine, veterinary science, public health, and kinesiology – created the case to bring students from different disciplines together.

The case was delivered virtually over two 90-minute sessions. Students were divided into small interdisciplinary breakout groups, each facilitated by faculty using a co-developed discussion guide. Students engaged with the scenario through PowerPoint slides that included narrative elements and multimedia content featuring a farmer, a physician, a veterinarian, and a public health expert. Group discussions were followed by a plenary session to synthesize insights and propose solutions.

Assessment involved pre- and post-session surveys measuring awareness across five dimensions, such as knowledge of diarrhea risk factors, consequences of flooding, public health strategies, and interdisciplinary collaboration.

Results showed significant gains in awareness in all areas, with the greatest increase in students' understanding of the interprofessional nature of the case. Notably, 96% of participants expressed interest in future One Health learning experiences.

## DISCUSSION

Among the 3,445 articles, published in peer-reviewed journal over a span of 40 years (1983–2023), many advocate for incorporating One Health and emphasize the need for transdisciplinary approaches, few provide detailed descriptions of curricular materials or instructional strategies, and we only identified three that described the development and implementation of concrete educational content—a striking gap in the published One Health content development for undergraduate medical education.

Moreover, while some articles advocate varied processes to develop One Health content, it is important to distinguish between content development - the process of designing educational materials – and content developed, the actual products such as syllabi, lesson plans, or case-based exercises. While the development process is often discussed in general terms, very few studies present the content developed in a form that can be reviewed, adapted, or implemented by other educators. This gap is concerning, as well-designed, shareable content is essential for preparing future physicians to understand and address the interconnections among human, animal, and environmental health. The absence of concrete materials limits the integration of One Health principles into medical training and may ultimately weaken our capacity to respond effectively to emerging global health threats.

Several systemic barriers may contribute to this lack of published content. For example, Docherty and Foley's survey (Docherty and Foley, 2021) of One Health programs in U.S. medical schools identified two key challenges: (1) limited resources and funding, as developing, piloting, and disseminating curricular content often requires substantial institutional investment; and (2) interdisciplinary barriers, as effective One Health education depends on collaboration across fields with differing languages, priorities, and academic cultures. It should be noted that these barriers were also noticed by others (Rabinowitz et al., 2017; Docherty et al., 2021; Yopa et al., 2023; Cai et al., 2024; Tucker et al., 2024). Therefore, these barriers are likely the reasons why we did not find many published articles on One Health content developed and implemented for medical student education.

Beyond these findings, an important consideration is that the scarcity of peer-reviewed publications on One Health curricula does not necessarily mean that medical schools have failed to act. It is plausible that many institutions have developed lectures, modules, or even integrated components of One Health into their programs but have not disseminated these efforts in peer-reviewed journals. Curricular innovations may remain internal due to limited

incentives for publication, lack of resources for formal evaluation, or prioritization of local educational needs over scholarly dissemination. In addition, some initiatives may be reported in grey literature, conference proceedings, or institutional reports that are not captured in traditional databases. Thus, our findings should be interpreted as highlighting a gap in published, peer-reviewed evidence rather than an absolute absence of One Health education in medical schools.

We acknowledge that it is not common for educators and researchers to publish curricular content in academic journals. However, unlike other disciplinary materials in medical education, One Health curricular content remains scarce. Given its transdisciplinary nature, which requires integrating expertise from human, animal, and environmental health, developing high-quality, comprehensive One Health curricula often exceeds the capacity of individual medical schools, particularly smaller schools, or those in resource-limited settings. These unique demands call for a different approach – that is, One Health educators need to actively publish detailed curricular content and educational resources. Doing so is in alignment of the need to view One Health curriculum development through the lens of the scholarship of teaching and learning (SoTL) framework (McKinney, 2004), which calls for systematic inquiry into student learning and peer-reviewed dissemination of findings to improve teaching and advance knowledge. Within this framework, developing, evaluating, and publishing curricular materials are not merely academic add-ons but integral steps in transforming teaching innovation into recognized scholarship. Adopting a SoTL perspective would encourage educators to document and share both process and outcomes, thereby enriching the collective evidence base of One Health education and fostering continuous improvement across institutions.

Additionally, it is critical that One Health researchers consider collaborating with medical educators to develop One Health content covering fundamental topics in ways and integrate it into medical curricula and then publish their work. This will promote accessibility and equity by providing medical schools around the world, especially in under-resourced regions, with ready-to-use, high-quality, transdisciplinary materials that they might otherwise be unable to create independently. It also ensures quality assurance, as peer-reviewed publication provides academic validation and affirms the rigor and relevance of the content for medical training. Furthermore, sharing curricular content fosters collaborative development, allowing for continuous refinement through feedback by educators across diverse institutional and cultural contexts. It enhances efficiency by reducing duplication of effort, allowing educators to focus more on effective implementation and local adaptation rather than recreating foundational content. Finally, the availability of shared materials supports global standardization by facilitating the development of common competencies and benchmarks, thereby advancing consistency in One Health education worldwide.

Future research should address not only the outcomes of One Health education—such as its impact on student learning and professional competencies—but also the development and delivery of educational content. Comparative studies examining different curricular models, instructional formats, and scalability across diverse institutional contexts would be especially valuable. However, progress in this area will depend on collaborations between medical educators and One Health researchers and greater scholarly attention to the documentation and dissemination of concrete instructional materials.

## LIMITATIONS

While this review is comprehensive, it has several limitations. First, we excluded non-English publications, which may have led to the omission of valuable contributions from regions where One Health integration may be more advanced. Second, since our search was limited to articles indexed in PubMed, we may have overlooked some relevant information published in other databases. However, given that most journals of medical education research and One Health are indexed in PubMed, our focus on this database should not be seen as a serious limitation.

## CALL TO ACTION

To advance the field of One Health education of medical students, it is essential that medical educators move beyond local implementation and actively disseminate their One Health curricula, teaching strategies, and assessment outcomes through peer-reviewed publications. Sharing such work not only validates institutional innovations but also enables comparative evaluation, replication, and refinement across contexts. Publication provides a platform for critical dialogue, fosters collaboration between medical schools and allied health disciplines, and helps build a collective evidence base that can inform accreditation standards and policy frameworks.

Importantly, this scholarly dissemination aligns with the principles of the SoTL. Framing One Health curricular development within the SoTL paradigm elevates it from isolated innovation to recognized educational scholarship, ensuring that the process and outcomes are visible, replicable, and impactful across institutions.

Without this shared scholarly exchange, One Health education risks remain fragmented, with institutions repeatedly reinventing content rather than building one another's progress. We therefore suggest viewing publication as a crucial step in translating local curricular innovation into sustainable global impact.

## ETHICS AND CONSENT TO PARTICIPATE

Not applicable

## COMPETING INTERESTS

The authors declare that they have no competing interests.

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## AUTHOR CONTRIBUTIONS

ZH, FB and ST conceptualized the project. ER, TM, KM, AB, AB, NM, and ZH designed literature search, screened, and reviewed articles. The first draft of the manuscript was written by ER, TM and ZH. All authors contributed to editing and revising the manuscript. All authors commented on and approved the final manuscript.

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