DISCUSSION PAPER

Core Competencies in One Health Education: What Are We Missing?

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Introduction

Today's public health challenges are complex and crosscutting. Antimicrobial resistance, pollution, food security, biosafety, biosecurity, and emerging and reemerging infectious diseases are associated with changes in land use, population growth, urbanization, global travel and trade, industrial activities, and climate change [1-5]. International stakeholders have made efforts to address these issues, such as the revision of the International Health Regulations (IHR) and development of Sustainable Development Goals (SDGs) and the Global Health Security Agenda [1,6,7]. However, in recent years, the proliferation of antimicrobial-resistant organisms infecting humans and animals, political and natural disaster-related food insecurity, and outbreaks of many diseases, such as Ebola, chikungunya, Zika virus, Middle East Respiratory Syndrome, cholera, plague, and yellow fever, have highlighted our vulnerability to emerging infectious diseases among other crises [1,8-10]. In response, a transdisciplinary approach among human, animal, plant, and environmental health disciplines, described as One Health, has gained support and visibility because of its capacity to synergistically address these challenges. Greater emphasis on the One Health approach has been suggested by several voluntary peer-to-peer reviews by countries seeking to evaluate their capacities to address infectious disease threats. These Joint External Evaluations (JEEs) have been conducted under the IHR to identify urgent gaps in participating countries' health security systems and to broadly promote capacity building [11]. In 2016, the JEE for the United States identified a major gap: inconsistent coordination across various health sectors at the federal, state, and local levels [12]. The United States was encouraged to develop a more formal One Health strategy to address these challenges. In response to this call, the Forum on Microbial Threats of the National Academies of Sciences, Engineering, and Medicine (the National Academies) formed a One Health Action Collaborative to evaluate the current status, successes, and challenges of deploying the One Health approach and to catalyze efficient and effective implementation.

An important step toward advancing such a strategy in the United States would be to apply consistent One Health core competencies in education. Lessons learned from infectious disease outbreaks in recent years have illustrated that training professionals in the One Health arena has the potential to improve epidemic and pandemic preparedness [13,14]. Furthermore, the National Academies recommended coordinating emergency preparedness and response as one of the major future roles of the United States in global health in 2017 [15]. Without a One Health approach, experts in environmental, animal, and human health will continue to address these challenges independently and in an uncoordinated fashion, missing the opportunity to maximize the benefits of shared knowledge, shared professional expertise, and available resources [16]. Beyond conceptual benefits of employing the One Health approach, such as building partnerships across institutional and disciplinary barriers for collaborative problem solving, the available evidence illustrates higher returns on health investments and technical efficiencies, such as avoiding duplicate logistic efforts through joint pathogen detection and human-animal

vaccination campaigns [17-20]. It is therefore a top priority for the United States to train future One Health leaders through sound, competency-based education that measures the learners' abilities to demonstrate specific skills [21].

Although the One Health approach has been championed in many academic and international organizations for decades, trends indicate an increase in the number of professional associations, scientific publications, and academic programs with a One Health theme only in recent years [22-24]. The authors of this paper have set out to understand the evolution of existing core competencies in One Health education, assess how core competencies are being applied in academic programs in the United States, and identify gaps that should be filled through formal recommendations. In this paper, we discuss the unique challenges facing the incorporation of One Health core competencies in educational programs and provide recommendations to advance their visibility and use.

Methods

Existing Core Competencies

A literature search for One Health core competencies was conducted on PubMed, as well as websites for governmental and nongovernmental organizations, academic institutions, and professional associations. Keywords for the search were "One Health core competencies" OR "One Health competencies" OR "One Health education." Furthermore, competencies for the master of public health (MPH) program were identified through literature search and online reports.

One Health Academic Degree Programs

One Health academic programs were identified through a literature search on PubMed, recommendations by experts, and a web-based search for academic degree programs using a combination of the following keywords: "One Health" OR "EcoHealth" OR "veterinary public health" OR "planetary health" OR "geohealth" OR "medical geography" AND "program" OR "degree" OR "bachelor's" OR "undergraduate" OR "master's" OR "graduate" OR "doctoral" OR "PhD." Additionally, a combination of keywords, "public AND health AND animal," "environmental AND health AND animal," "agriculture AND health AND human," "agriculture AND health AND environment," were used. "Public health" and "agriculture health" were used in combination with other keywords, because a large number of public health and agriculture health programs did not result in One Health–related programs being identified (for example, there are 186 accredited public health schools and programs, but most are not using a One Health approach, nor do they include animal and/or environmental health) [25]. Academic degree programs were included in the study if they were based in the United States and the degree name included "One Health," were described as a One Health program, or were taught with an interdisciplinary approach linking human, animal, and environmental health disciplines or professions.

Available information on the academic institution, department, state, name of degree, time-to-degree, eligibility, and year of program establishment were extracted and recorded in a database. Course descriptions and degree requirements for each of the programs were evaluated to complete any missing information. Furthermore, all program administrators were contacted by e-mail to complete any missing information not easily accessible in the public domain. Available information for each degree program, such as the list of core competencies, course descriptions, and degree requirements, was reviewed and assessed if key areas were mentioned, included, or taught in the degree program. While acknowledging that they are strongly interconnected, inclusion of the following key areas were assessed for each curriculum: antimicrobial resistance, zoonoses, food safety/food security, geographic information systems, emerging infectious diseases, epidemiology, plant biology, law, economics, toxicology, agriculture/livestock, policy, ecology/environmental health, vector-borne diseases, conservation/wildlife, and social and behavioral sciences. Both key neglected areas, such as plant biology and food security, and areas upon which the One Health approach has previously focused, such as zoonoses and emerging infectious diseases [26], were identified through discussions among the members of the National Academies' One Health Action Collaborative. If the key area was represented in at least 75 percent of all identified degree programs, it was defined as "well represented." Conversely, if the key area was represented in less than 25 percent of all identified degree programs, it was defined as "underrepresented." Furthermore, we assessed whether programs included applied practical training and communications in their curricula. Inclusion of applied practical training in an academic curriculum was defined as the requirement to participate in

practical experiences, capstone projects, internships, or externships related to their study focus.

Findings

Existing One Health Core Competencies

We identified 24 manuscripts and reports related to One Health and education and closely evaluated seven in the final review. The comprehensive review by Frankson et al. (2016) summarized the development and synthesis of One Health core competencies domains [27]. There were several past initiatives, including the Bellagio working group in 2008, the Stone Mountain Training Workgroup in 2010, and the US Agency for International Development RESPOND initiative in 2011, as well as a synthesis of competency domains completed in Rome in 2012 [27-29]. In addition, a university network in Southeast Asia defined One Health core competency domains and learning objectives in 2013 [30]. Since then, One Heath core competency recommendations have not been updated and provided as a public resource. Although the three aforementioned One Health competency frameworks were developed individually, similar core competency domains were identified. Seven domains were identified in the Rome synthesis in 2012: (1) Management, (2) Communication and informatics, (3) Values and ethics, (4) Leadership, (5) Team and collaboration, (6) Roles and responsibilities, and (7) Systems thinking. Health sciences was not identified in these competency domains. Keywords such as "cross-disciplinary," "diversity of disciplines," and "interdependency" were used in examples provided for these competency domains.

There is currently no accrediting body for One Health degree programs, unlike public health degree programs, understandably because One Health is considered more of an approach and less of a discipline; therefore, no standardized structure or expectations exist for these programs. In 2016, the National Academies held a workshop titled "The Role of Accreditation in Enhancing Quality and Innovation in Health Professionals," in which attendees discussed the accreditation of One Health education and associated challenges, especially given the globalization of the workforce [31]. The workshop explored the history of accreditation within veterinary medical education and acknowledged that standardized certification could be challenging when there are different societal expectations of professions working in varying cultural contexts.

Although public health is usually focused on human health, whereas One Health takes a broader view, the two have much in common. They share the goal of promoting health and well-being at the population level through interdisciplinary collaboration, and they both require practitioners with knowledge and skills that span multiple domains. Indeed, the overlap between core competencies in the One Health Rome synthesis and the accredited MPH degree includes the competency domains of "leadership," "systems thinking," and "communication and informatics." Now the One Health approach is beginning to be integrated into public health education. In October 2016, One Health was added to the accreditation criteria by the Council on Education for Public Health, the accrediting body for US public health schools [32]. The One Health concept is now included in a section titled "Foundational Public Health Knowledge," and all MPH and doctor of public health students are expected to be able to "explain an ecological perspective on the connections among human health, animal health, and ecosystem health (e.g., One Health)" at the time of program completion [32]. This core addition is to be incorporated by the end of 2018. In addition, a recent study advocated for the inclusion of One Health in medical school education, because One Health aligns with the concept of caring for patients as a whole and has gained a high level of acceptance among international organizations [33].

One Health Academic Degree Programs

One Health education has been championed around the world by regional university networks [30,34] and academic institutions, as highlighted in a recent Western Europe review [35]. In the United States, we identified at least 45 One Health academic degree programs (see Figure 1). The majority of One Health academic degrees are new—19 out of 23 academic programs (83 percent) for which the founding year could be identified were established in or after 2002. Additionally, two new programs were launched in 2017 (see Figure 2). Among 45 programs, 27 were master's level (60 percent), 10 were bachelor's level (majors and minors) (22 percent), and 8 were doctoral programs (18 percent). Time-to-degree varied according to the educational level of the degree program. All bachelor's programs were four years; master's programs varied from one to five years, including full-time, part-time, dual degree, or online courses; and doctoral programs were largely unspecified. Master's degrees included 18 MPH de-

grees, 6 master of science degrees, 1 master of preventive veterinary medicine, 1 master of health sciences, and 1 master of food and agriculture law and policy. Six degree programs (13 percent) included the words "One Health" in the official title, such as "MPH in One Health" and "Bachelor with One Health minor." There were 35 (78 percent) academic programs in public universities and 10 (22 percent) programs in private universities. All but one degree program were housed under colleges, departments, or schools of disciplines related to health sciences, and one program was offered in a law school. It is possible that additional programs exist but were not identified because they did not meet our search criteria. Among the 45 identified programs, 14 had competencies that were publicly available online (31 percent), and another 4 programs provided a list of competencies once they were contacted directly (9 percent). The remaining 27 programs (60 percent) did not explicitly state core competencies on their website, nor did they have them available when contacted. Some reasons given for lack of specific competency listings were that they were reflected in the program descriptions or that the curriculum was fitted to individual students' needs and interests. Therefore, how and if core competencies have been applied in these programs is unclear.

Based on the identification of core competencies, or the programs' course descriptions and degree requirements in cases when core competencies were unavailable, it was clear that some key areas were included in the curriculum of more degree programs than others. There were two well-represented disciplines, which were identified in 75 percent or more of all degree programs, and three underrepresented disciplines, which were identified in less than 25 percent of all degree programs. Well-represented disciplines were epidemiology and environmental health/ecology. Underrepresented disciplines were plant biology, antimicrobial resistance, and law (see Figure 3). Some programs were specifically tailored to conservation (n=1), occupational health (n=3), entomology (n=3), and policy or legal issues (n=2) employing a One Health approach.

Furthermore, 31 out of 45 One Health programs (69 percent) placed emphasis on integrated training and collaborative work between academia and public health agencies in the form of practical experiences, capstone projects, internships, or externships. Communication was mentioned in descriptions or competencies in 20 out of 45 programs (44 percent).

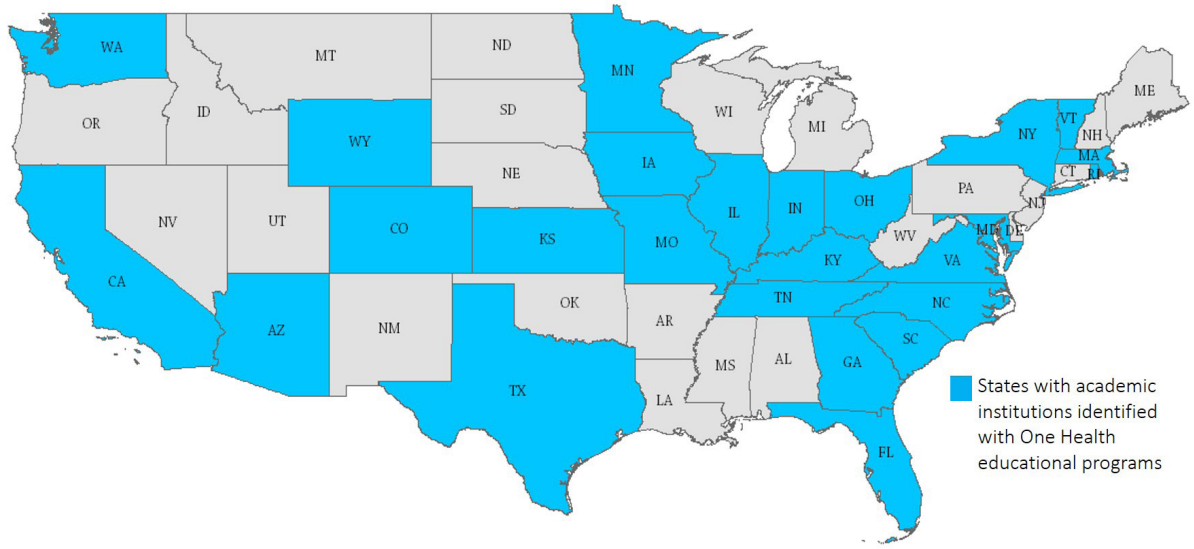

FIGURE 1 | Geographic Location of One Health Programs by State

SOURCE: Togami et al., "Core Competencies in One Health Education: What Are We Missing?," National Academy of Medicine.

NOTE: One Health academic programs were identified in the contiguous United States only.

1947 CDC [a] establishes Veterinary Public Health Division
2004 Manhattan Principles are released to holistically prevent epidemics and maintain ecosystem integrity
2007 AMA [b] and AVMA [c] call for increased collaboration between human and animal health
2009 USAID [d] establishes Emerging Pandemic Threats program
CDC establishes One Health Office
2010 FAO-OIE-WHO Tripartite [e-g] publishes collaborative concept note
United Nations and World Bank set One Health framework for animal and pandemic influenza
2017 G20 [h] recommends One Health approach to address antimicrobial resistance

FIGURE 2 | Founding Year of One Health Programs by Educational Level and Major Events in One Health

SOURCE: Togami et al., "Core Competencies in One Health Education: What Are We Missing?," National Academy of Medicine.

NOTES: Founding years were available from 24 of 45 programs. If a program was founded in one year and merged with another program later, the initial year was included in the figure. Major events in One Health were adapted from publicly available resources [36-41].

[a] CDC = US Centers for Disease Control and Prevention; [b] AMA = American Medical Association; [c] AVMA = American Veterinary Medical Association; [d] USAID = United States Agency for International Development; [e] FAO = Food and Agricultural Organization of the United Nations; [f] OIE = World Organisation for Animal Health; [g] WHO = World Health Organization; [h] G20 = Group of Twenty

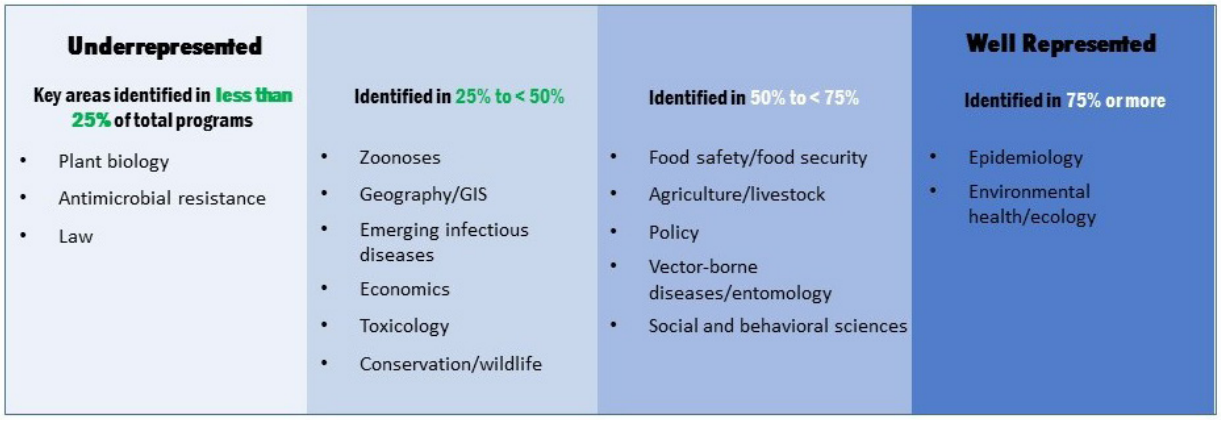

FIGURE 3 | Key Areas Represented in One Health Degree Programs

SOURCE: Togami et al., "Core Competencies in One Health Education: What Are We Missing?," National Academy of Medicine.

NOTES: "Total programs" refers to the 45 One Health academic programs identified in this study. GIS = geographic information system.

Discussion and Recommendations

This study, identifying and characterizing 45 One Health educational programs in the United States, illustrates that the One Heath approach is now employed by numerous schools and disciplines as a means to educate students. Identification of core competencies, course descriptions, and direct communication enabled us to compare key areas taught and disciplinary emphases. We support efforts by many academic institutions to launch and continue to provide education employing a One Health approach. The variety of educational levels from undergraduate to doctoral, tailoring of programs to specific areas of emphases such as policy, law, and conservation, as well as programs being administered by schools of various disciplines not limited to the veterinary field, indicate a diverse and growing pool of One Health educational programs. Academic programs showed efforts to incorporate multiple disciplines, as well as goals of exposing students to real-life work environments as part of their curricula. However, there were some gaps that could be filled to further strengthen One Health education. In light of the above, the authors of this paper suggest the following recommendations based on the findings discussed here, as well as insights from individual participants in the National Academies' One Health Action Collaborative.

Recommendations

1. Clearly state core competencies, including proficiency in at least one health science

Academic institutions delivering One Health programs should make voluntary commitments to apply One Health core competencies to their programs. Programs will vary in their specific curriculum, their focus, their student base, and their expected subject matter mastery; however, program administrators can draw from these recommended core competencies to craft program-specific lists appropriate to their institutional goals. A consistent application of core competencies will mitigate the issue of inconsistent skill sets in graduates across disparate departments or schools. Table 1 outlines the core competencies we recommend, adapted from the most recently established undergraduate-level degree we identified with publicly available competencies, the bachelor of science degree in global disease biology at the University of California, Davis [42]. These competencies can be reviewed and applied according to the level of mastery that is intended for students in specific academic programs.

2. Educate future professionals in the One Health arena in disciplines that are currently well represented, as well as disciplines that are currently not well represented

Of the One Health target areas, antimicrobial resistance, law, and plant biology have received the least amount of focus in the current educational programs reviewed here and thus represent gaps in curricula. To equip future One Health professionals with a wide array of skill sets for problem solving, we recommend that academic degree programs provide students access to a multidisciplinary curriculum and faculty. As an example, we should discuss disease management in the context of various drivers of disease (for example, biological and environmental [natural, built, socioeconomic, and so on]) and explore the range of species and environments that affect disease transmission, including insects, plants, food, and water [43]. Research methods, novel diagnostic techniques, and protocols from the plant-based agricultural and food safety fields could be used as models for disease management in other types of populations; the plant biology field, for example, uses risk assessments for pathogen introduction, surrogate models, and next-generation diagnostics in developing disease control approaches [44]. One Health program faculties should include professionals not usually engaged in medical education, such as vector entomologists, food production professionals, and plant pathologists.

It is also important for programs to recognize and stress that the One Health approach has a broader application that reaches beyond addressing infectious disease threats in humans and animals. The interconnectedness between changes in climate, land use, population dynamics, foreign policy, biosecurity, economics, trade, agriculture, and natural resources are also important issues under the One Health umbrella [45]. For example, accelerating urbanization and changes in climate underlines the importance of ensuring that the food on our tables is safe and that people have sustainable access to nutritious and healthful food [1,46]. As institutions consider revising existing curricula or developing new programs, emphasizing underrepresented areas in One Health education for programs considering curricular revision or development will help drive paradigm shifts, such as the one needed to

Table 1 | Recommended Core Competencies for One Health Education

Health Knowledge	Global and Local Issues in Humans, Animals, Plants and the Environment	Professional Characteristics
Objective To demonstrate knowledge of established and evolving transdisciplinary One Health sciences, including those relevant to public health, animal health, environmental sciences, and modern agriculture	*Objective* To demonstrate an understanding of historical, cultural, political, economic, and scientific aspects of complex and emerging health problems that are amenable to the One Health approach	*Objective* To demonstrate the ability to understand and apply principles of research and evaluation methods to policy and health program implementation, as well as apply scientific findings to real-life situations
• Characterize the etiology, evolution, and ecology of infectious disease agents of people, animals, and plants that are of importance to health. • Describe the main transmission routes for toxins, pathogens, and resistance genes, including human-animal-plant-environmental exposures, as well as vector-borne, waterborne, and airborne cycles. • Explain epidemiologic principles used to characterize problems that involve human, animal, plant, and environmental components. • Understand scientific principles such as biological complexity, genetic diversity, and interactions of systems from individuals to ecosystems that influence modern complex challenges in human, animal, plant, and environmental health. • Identify common cultural and socioeconomic determinants and effects of illness, including poverty, residential geography, cultural practices, education, nutrition, and resource security. • Explain how biosurveillance, diagnostics, and therapeutic countermeasures are deployed. • Describe interventions used to prevent disease and improve human, animal, plant, and environmental health at the individual, community, and population levels.	• Describe the biological principles, scope, and complexity of disease in people, animals, plants, and the environment. • Understand the effects of global change on health and how both local and global factors affect disease transmission within and between countries. • Identify and understand the origins and determinants of health (human, animal, plant, and environment) as related to disease. • Compare and contrast health and non-health consequences of diseases and exposures, including social and behavioral, economic, and political effects across global regions. • Recognize major challenges and opportunities to improve health in a global and local context through practical and applied training. • Demonstrate a basic understanding of pre- and post-production food safety. • Understand the structure and responsibilities of the public health system, including the local, state, and national levels of government. • Describe the relationship among various key One Health stakeholders locally and globally.	• Describe the benefits and challenges of a multidisciplinary, integrative approach when implementing studies regarding health concerns at the human-animal-plant-environment interface. • Effectively communicate, both orally and in writing, scientific findings to the scientific community, non-health-related academics, public audiences, media, and policy makers. • Demonstrate scientific quantitative skills, such as the ability to evaluate experimental design, interpret scientific findings, and develop discussions, as well as provide implementable recommendations. • Demonstrate the ability to build and manage a transdisciplinary team and apply principles to conduct ethical, scientifically sound research that will inform policy. • Develop a plan to translate research findings and new discoveries into health policies, community programs, interventions, and public education in a manner that is sustainable, culturally relevant, and economically feasible.

SOURCE: Togami et al., "Core Competencies in One Health Education: What Are We Missing?," National Academy of Medicine.

move beyond food safety to food security. Broadening the skill base of health professionals involved in One Health education will also help to strengthen IHR core capacities, such as pandemic preparedness, and to accelerate progress toward achieving SDGs.

3. Continue to focus on practical and applied training

Most One Health degree programs already emphasize practical training, where students are required to participate in practical experiences, capstone projects, internships, or externships related to their studies. One Health programs with a focus on working in a nonacademic setting will allow future One Health leaders to work effectively in various agencies, ranging from local and state agencies to international organizations. In addition, training in real-life settings equips future One Health practitioners with cultural competencies, such as understanding the importance of fostering local ownership of a project, and in undertaking multisectoral and interdisciplinary collaboration when working in lower- and middle-income countries. Practical fieldwork develops these skills in a way that classroom education cannot, and it is vital to trainees' success, both in the public and private sectors.

4. Emphasize communication in One Health education - coordination and collaboration are essential to the One Health approach

Communication is one of the seven domains in the existing competency domains, but it remains absent in many extant One Health programs (25 out of 45 programs, 56 percent). Because coordination and collaboration across disciplines is essential to the One Health approach and shortcomings in articulating the One Health agenda have been a challenge [26], training in communication should be further emphasized and applied in all One Health degree programs. Proficiency includes communicating to build and manage a transdisciplinary team, communicating to academics and professionals across various disciplines, and communicating to policy makers and the public, as well as communicating in different cultural settings. Anticipated effects of improving communications training include clear and timely risk communications during health emergencies and increased stakeholder engagement around the One Health approach. As further evidence becomes available, professionals should be prepared to communicate solutions derived through the One Health approach, as well as the general benefits and feasibility of employing the One Health approach as global health challenges continue to emerge.

A Step-by-Step Approach to One Health Core Competencies

We encourage program directors and administrators to employ the core competencies recommended in this paper, as well as to consider other existing core competency domains and established disciplinary-based accreditation standards in their curricular development and revision, following the six steps shown in Figure 4. This approach is intended to provide a framework for administrators to become familiar with competency-based education in One Health, clearly define their program objectives, and optimize core competencies for their academic programs. Voluntary commitment to employing One Health core competencies by program administrators would lead to a stronger, competency-based education, no matter what the program focus may be.

Future Directions

It is important to define, develop, evaluate, improve, and continue to refine One Health education, not only in One Health degree programs but also in existing public health, environmental, veterinary, and medical curricula. We suggest that One Health academic degree programs be built on a foundation of core competencies and that an emphasis on practical skills is needed. In addition, it is important that new and extant initiatives with common interdisciplinary approaches, such as planetary health, geohealth, ecohealth, evolutionary medicine, and One Health, communicate and stay connected. Moving forward, we must fill gaps, as well as evaluate career trajectories, of One Health degree program graduates. An analysis of One Health professionals in the workforce and examples of One Health successes from applying core competencies could be useful, including evaluation of the willingness of funding agencies to support investments in One Health educational programs, either directly or through active recruitment of graduates into career positions. The One Health movement has gained growing support in recent years and could continue to develop and be recognized as effective through improved education, especially if graduates are shown to be valuable assets in the health workforce and a driving force in global health problem solving.

A Step-by-Step Approach to Applying One Health Core Competencies

Suggestions for Academic Program Administrators

Step 1 **Understand the benefits and challenges of competency-based education.**

- ☐ If not already, become familiar with the basics of competency-based education, the development process of the competency model for the master of public health degree, and previous efforts regarding One Health core competencies, as well as other references.

Step 2 **Evaluate and catalogue the objectives of your academic degree program.**

Step 3 **Review the curriculum structure of your program and the list of core competencies, if available.**

- ☐ Compare them with the One Health competency domains, as well as subdomains and competency examples from past initiatives, such as the US Agency for International Development RESPOND Initiative's One Health Core Competency Domains, Subdomains, and Competency Examples.
- ☐ Consider incorporating the core competencies and skill sets suggested above.

Step 4 **Consider adding missing disciplines and skill sets to your existing program.**

- ☐ Include key focus areas in introductory courses to orient students to One Health early in the curriculum.
- ☐ Identify strengths and weaknesses of your program, in relation to core competencies.
- ☐ Add guest lectures for gaps in faculty expertise.

Step 5 **Make the core competencies of your program publicly visible.**

- ☐ Make the core competencies available on your website and in recruiting materials for the benefit of both prospective students and employers of your graduates.

Step 6 **Solicit feedback from students, graduates, faculty, and alumni to continue revising and optimizing core competencies and associated curricular offerings.**

- ☐ Consider a continuous quality improvement plan or other regular systematic appraisal.
- ☐ Determine a process by which to incorporate feedback, improvement, and innovation into the curriculum.

FIGURE 4 | A Step-by-Step Approach to Applying One Health Core Competencies in Academic Programs

SOURCE: Togami et al., "Core Competencies in One Health Education: What Are We Missing?," National Academy of Medicine.

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