CABI One Health

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# Advancing One Health: Updated core competencies

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## Abstract

One Health recognises the interdependence between the health of humans, animals, plants and the environment. With the increasing inclusion of One Health in multiple global health strategies, the One Health workforce must be prepared to protect and sustain the health and well-being of life on the planet. In this paper, a review of past and currently accepted One Health core competencies was conducted, with competence gaps identified. Here, the *Network for Ecohealth and One Health (NEOH)* propose updated core competencies designed to simplify what can be a complex area, grouping competencies into three main areas of: Skills; Values and Attitudes; and Knowledge and Awareness; with several layers underlying each. These are intentionally applicable to stakeholders from various sectors and across all levels to support capacity-building efforts within the One Health workforce. The updated competencies from NEOH can be used to evaluate and enhance current curricula, create new ones, or inform professional training programs at all levels, including students, university teaching staff, or government officials as well as continual professional development for frontline health practitioners and policy makers. The competencies are aligned with the new definition of One Health developed by the One Health High-Level Expert Panel (OHHLEP), and when supported by subject-specific expertise, will deliver the transformation needed to prevent and respond to complex global challenges.

## One Health Impact Statement

Within a rapidly changing global environment, the need for practitioners competent in integrated approaches to health has increased substantially. Narrow approaches may not only limit opportunities for global and local solutions but, initiatives that do not consider other disciplines or social, economic and cultural contexts, may result in unforeseen and detrimental consequences. In keeping with principles of One Health, the *Network for Ecohealth and One Health (NEOH)* competencies entail a collaborative effort between multiple disciplines and sectors. They focus on enabling practitioners, from any background, at any level or scale of involvement, to promote and support a transformation to integrated health approaches. The updated competencies can be layered with existing disciplinary competencies and used to evaluate and enhance current education curricula, create new ones, or inform professional training programs at all levels -including for students, teachers and government officials as well as continual professional development for frontline health practitioners and policymakers. The competencies outlined here are applicable to all professionals and disciplines who may contribute to One Health, and are complimentary to, not a replacement for, any discipline-specific competencies. We believe the NEOH competencies meet the need outlined by the Quadripartite's (Food and Agriculture Organisation, United Nations Environment Programme, World Health Organisation, World Organisation for Animal Health) Joint Plan of Action on One Health which calls for cross-sectoral competencies.

**Keywords:** One Health, planetary health, ecohealth, education, integrated, systems thinking, interdisciplinary, transdisciplinary, workforce development, capacity building

## Introduction

One Health challenges are not simply health problems. The past decade has seen increasing recognition of the importance of a diversity of perspectives covering medical, veterinary, ecological and socio-economic aspects of health. A systematic review of 100 One Health networks showed that more than two-thirds engaged across human, animal and environmental health (Chiesa et al., 2021). A recent growing number of One Health organisations or initiatives are mirrored by an increase in published peer-reviewed literature citing One Health (Galaz et al., 2015; Khan et al., 2018) and those describing the scope of One Health have further broadened to include social, anthropological, theological, philosophical, political and economic features. However, the role of these wider social health determinants is still often overlooked in practice (Galaz et al., 2015; Keune et al., 2017). A survey of European One Health initiatives revealed inequity between sectoral priorities with human and animal health often favoured (Chiesa et al., 2021). Consequently, veterinary and public health professionals have had the most prominent representation within One Health (Galaz et al., 2015; Zinsstag, 2012), and there have been considerable gaps in the ecological or social remit or focus of initiatives and curricula (Galaz et al., 2015; Khan et al., 2018; Rocheleau et al.,

2022). Some of these gaps have become more recognised over time, and have led to expanded movements with broader scopes such as Eco(system) Health and Planetary Health (Assmuth et al., 2020). The implementation of more integrated approaches to health, including One Health, is thus characterised by varying interpretations of what health and well-being mean in practice and hindered by competing priorities and a lack of coordination within global health systems (Lee and Brumme, 2013). Facilitation and delivery of shared health objectives across sectors, co-constructed with all relevant actors and stakeholders, operational within any context and at any level, requires an updated set of operative core One Health competencies. The integration of these updated One Health competencies at all levels is vital to unify sectoral objectives and progress systems understanding, helping to thereafter best implement One Health initiatives. These competencies should facilitate potential One Health practitioners from a broad range of backgrounds to work together across disciplines (such as natural or social sciences), sectors (such as policy or economics), with those across all scales (such as community networks or international organisations).

The authors, on behalf of the Network for Ecohealth and One Health (NEOH), propose an updated set of One Health core competencies, based on a global analysis of current One Health educational programs and the changing demands of One Health, to improve workforce capacity for One Health action. These updated competencies complement discipline-specific or technical skills currently prioritised in learning outcomes for a broad range of potential stakeholders and, respond to the Quadripartite's call for 'cross-sectoral competencies' in their Joint Plan of Action on One Health (FAO et al., 2022).

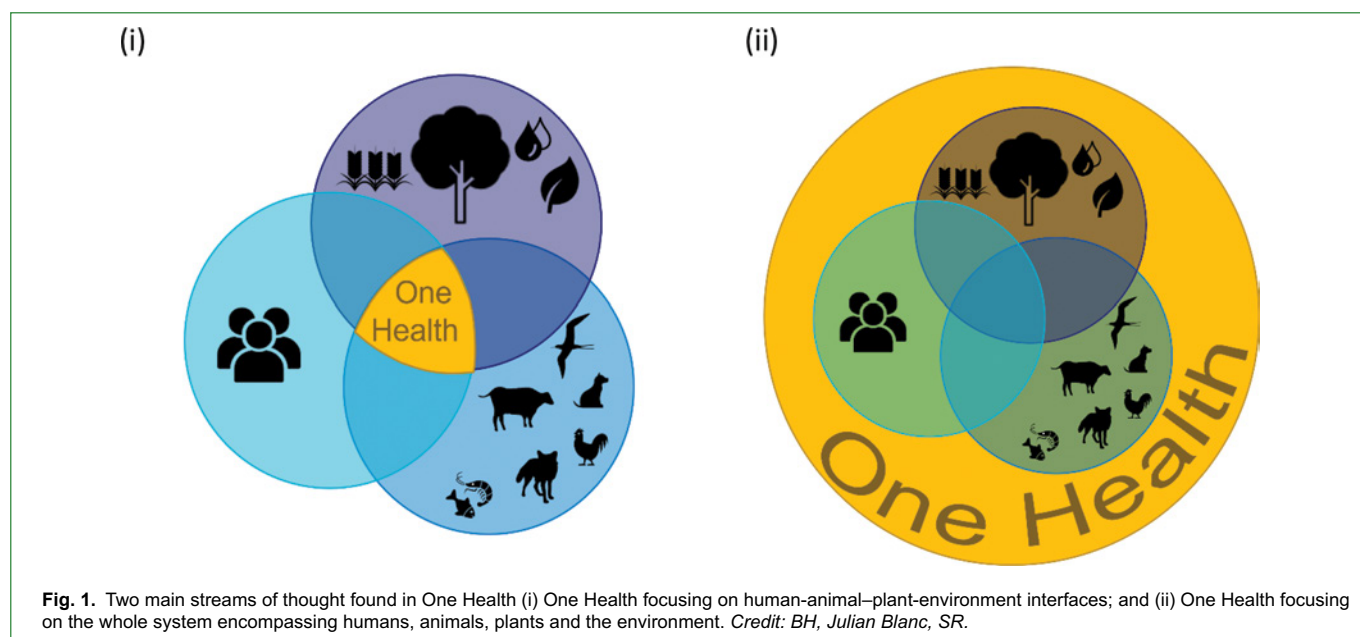## Evolution of thought in One Health

In the broader context of science and policy, One Health in theory and practice can be divided into two distinct streams of thought (Figure 1). The first, and older, stream focuses on reducing risks of health hazards at the human-animal–plant-environment interfaces with the aim to prevent, prepare, respond to and mitigate disease, primarily in humans, secondarily in production or a safe environment. Animals to ensure food safety and security, and thirdly in other animals including wildlife. Priority concerns include zoonotic, emerging and food-borne infections, antimicrobial resistance, biosecurity and biocontainment and disease surveillance. The second, and more recent, stream of thought considers the health of humans, animals, plants and the environment at the level of the system with a focus on the linkages between them, as well as on the underlying drivers that shape and influence these systems, such as global capital flows. It focuses on mechanisms to design and foster social-ecological systems (SES) that will sustain animals, people, plants and ecosystems. It requires current societal and institutional structures and practices to evolve from placing prominence on disease and disease mitigation, to concentrating on promoting healthy systems with sustainability, intergenerational equity, and balanced health across different systems. This necessitates reflecting on the socio-economic, geopolitical and environmental rootcauses of health across various levels of SES, with a move towards sustainable wellbeing within planetary boundaries and advancement towards social justice. Global food systems, for example, have a complex web of influences and impacts, from needing to understand and accommodate the cultural importance of food and food production to geopolitical influences such as conflict disrupting international

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**Fig. 1.** Two main streams of thought found in One Health (i) One Health focusing on human-animal–plant-environment interfaces; and (ii) One Health focusing on the whole system encompassing humans, animals, plants and the environment. *Credit: BH, Julian Blanc, SR.*

trade, alongside concerns for the environmental sustainability or ethics of current dietary choices and the changing nature and distribution of malnutrition. One Health competency must be adequately applicable across both streams.

In line with the evolution to a systems-based interpretation for One Health approaches, a more comprehensive, definition of One Health has been proposed by the One Health High Level Expert Panel (OHHLEP), an advisory panel to the Food and Agriculture Organisation (FAO), World Health Organisation (WHO), World Organisation for Animal Health (WOAH) and the United Nations Environment Programme (UNEP):

> "One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development."

> OHHLEP et al. (2022).

As societies and demands in health continue to change, practitioners and stakeholders will benefit from acquiring enhanced competencies that reflect the evolving nature of One Health. Professional associations in competency-based settings often expect regular review and updating of competencies (Mulder, 2022). In the absence of professional One Health associations, it falls to the One Health community to update competencies in line with changes in attitudes and thinking.

## History of competency frameworks in One Health

One Health competencies reflect the desired fundamental knowledge, skills and attitudes of a person trained and working in One Health. The broad range of One Health initiatives includes any organisation, project, policy or group which vary in their methodology and implementation but are bound by a common goal or tend to have specific operating principles, defined by ways of thinking systemically, planning comprehensively and working in transdisciplinarity (Rüegg et al., 2017). Here we propose updated

core One Health competencies that reflect the evolution of thought towards systems-based approaches, forming the basis for wider implementation through competent professionals who have the fundamental knowledge, skills and attitudes required for successful One Health implementation.

We build on previously proposed One Health competency frameworks. In 2007, a group of authors centred on the need for health professional training to facilitate transdisciplinary thinking and approaches (Salzburg Global Seminar, 2007). There was consensus that these "One Health" practitioners had unique professional competencies, complementing their individual knowledge and depth of expertise (Frankson et al., 2016). Between 2008 and 2011, three separate groups independently composed core competencies for professionals working within One Health. Firstly, the Bellagio Working group, sponsored by the Rockefeller Foundation, identified competencies for global food systems (Frankson et al., 2016). The Stone Mountain Meeting (SMM) training workgroup, hosted by the US Centre of Disease Control and Prevention (CDC), aimed to provide a roadmap for One Health implementation (CDC, 2010). Finally, the USAID/RESPOND programme funded a multi-agency workgroup that compiled a set of One Health core competency domains[a] (Hamilton et al., 2015). Individual participants and organisations, including from these initiatives, in addition to staff from the Rockefeller Foundation, CDC, FAO and the University of Minnesota, then contributed to the 2012 Rome Synthesis framework (Frankson et al., 2016). Similar core competencies were identified by the groups, despite their contributors being from different backgrounds and specialist fields. The seven major consensus domains identified at the Rome Synthesis were management, communication and informatics, values and ethics, leadership, team and collaboration, roles and responsibilities and systems thinking, seen in Table 1. The groups, organisations and meetings that contributed and led to the Rome Synthesis, and the Rome Synthesis itself, centre on competencies to prevent and manage the complex global disease challenges at the convergence of the human, animal and environmental health interfaces, with considerable focus on emerging threats to the human population. Situating these

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[a]Core Competency: a measurable knowledge, skill, or behaviour that every One Health practitioner must have. Competency Domain- a set of competencies (derived from key characteristics) that are grouped together in a local category.

recommended competencies within the first stream of thought in One Health as described in Figure 1.

A paper by Togami et al., (2018) highlighted challenges to incorporating One Health competencies into educational programmes, also identifying gaps in provision and making recommendations for inclusion of their competencies into formal education curricula. Challenges identified included not clearly stating the necessary core competencies and selected disciplines not being well-represented within programmes. The authors recommended inclusion of One Health education in all disciplines (particularly those not well-represented) with a focus on practical and applied training, and emphasis on communication, coordination and collaboration. The resulting competencies identified were divided into three categories: health knowledge, global and local issues in humans, animals, plants and the environment, and professional characteristics. In this framework, although there is primarily emphasis on competencies to respond to disease threats, there is a subtle shift towards the second stream of One Health thought (Figure 1); the broader consideration of the underlying drivers of disease within a system.

Table 1 illustrates similarities between Togami's framework and the Rome Synthesis. The professional characteristics described by Togami et al., (2018), largely encompass five of the seven Rome synthesis domains, and both frameworks emphasise awareness of 'big picture' thinking applied to problems and their solutions.

## One Health Core Competencies developed by the Network for Ecohealth and One Health (NEOH)

In the interests of continuing this advancement in One Health and embracing the evolution of One Health thinking to that shown in the second stream of Figure 1, existing One Health competencies were updated. This was through a process of consultation with NEOH members building on a legacy of publications, workshops and conferences from the Network since 2014. NEOH co-defined characteristics of One Health initiatives for evaluation, systematically searched scientific literature to identify existing tools, frameworks and indicators; and developed an evaluation framework (Rüegg et al., 2018a). This process uncovered underlying values and attitudes of the community of practice and resulted in a consultation on principles as a foundation for a sustained network of practitioners. In preparation of an entry-level textbook for One Health, the NEOH authors and collaborators reflected on the competencies the book would need to address

**Table 1.** A comparison of previously proposed competencies in One Health.

| Rome Synthesis Major Domains (Frankson et al., 2016) | Core Competencies for One Health Education (Togami et al., 2018) |
|---|---|
| Management:<br>- Able to manage cross-disciplinary teams—understands roles and responsibilities of the team and its individual members—holds team accountable | Professional characteristics:<br>- Understands the benefits and challenges of a multidisciplinary approach<br>- Effectively communicates with all audiences and stakeholders<br>- Conducts ethical and scientifically sound processes<br>- Translates findings into policies, programs and interventions in a manner that is sustainable and culturally relevant |
| Communication and informatics:<br>- Utilises diplomacy, able to negotiate, able to resolve conflicts—achieves collaboration | |
| Values and ethics:<br>- Values honesty, possesses strong self-awareness and integrity—possesses integrity | |
| Leadership:<br>- Advocates for change- fosters a changing environment—understands individual and shared leadership models—possesses an external awareness (social, political, legal and cultural) | |
| Team and collaboration:<br>- Identifies shared values and goals—values diversity of discipline, culture, ideas, background, and experience—establishes trust—thinks strategically | |
| Roles and responsibilities | |
| Systems thinking:<br>- Awareness of the big picture and interdependency of stakeholders—understands and embraces a One Health approach able to identify a problem and its impact on the system. | Global and local issues in humans, animals, plants and the environment:<br>- Understands historical, cultural, political, economic and scientific aspects of complex and emerging health problems.<br>- Recognises major challenges and opportunities to improve health on a global and local context, understands the structure of stakeholders, locally and globally. |
| | Health Knowledge:<br>- Demonstrates knowledge relevant to transdisciplinary sciences, including public health, animal health, environmental sciences and agriculture.<br>- Knowledge of aetiology, ecology and transmission of infectious diseases. Understands epidemiological principles.<br>- Ability to identify common cultural and socioeconomic determinants and effects of illness.<br>- Describes interventions used to prevent disease at the individual, community and population levels. |

to serve the successful implementation of One Health. An initial set of proposed competencies, based on existing literature and the work conducted in NEOH, was presented to all authors on a shared web platform; feedback was invited from all. The feedback was incorporated by one of the authors (BH) and an updated set of competencies was shared for a second iteration for review in 2021 with the current network of over 50 members. The resulting competencies were presented initially at the One Health conference in Oslo in November 2021 to gain feedback also from a wider audience.

Nine core competencies were identified, falling across three broader categories of skills, values and attitudes, and knowledge and awareness, as seen in Table 2 and Figure 2.

A One Health competent person is able to define and study issues spanning human, animal, plant and environmental systems, demonstrating big-picture awareness and agility to move across levels of literacy, scales or seniority. They can effectively engage in respectful communication and partnerships with individuals and groups from different backgrounds, disciplines, sectors and cultures to reach common goals. One Health competent individuals exhibit sensitivity to equity and justice considerations in human terms, and across animal, plant and environmental concerns, upholding the highest ethical conduct. One Health competent practitioners are humble and active learners, eager to collaborate with people from other disciplines and sectors, recognising the need to reflect on the continuous learning process. They can understand and convey theoretical and methodological pluralism, allowing space for alternative and local knowledge, and possess the capability to manage the resulting ambiguity, paradox and uncertainty. This level of competence can help deliver the expected outcomes of integrated approaches to health such as societal engagement and stewardship, equity, efficacy and efficiency, allowing the sustainable improvement of health and wellbeing of all species (Rüegg et al., 2017).

## Discussion

Within a rapidly changing global environment, the need for practitioners and scientists trained and competent in integrative approaches to health has increased substantially. One Health practitioners are suitably positioned to act as agents of change in this domain (Sidikou et al., 2021). Therefore, NEOH proposes updated One Health core competencies to reflect the evolving narratives in One Health, from the former anthropocentric view of disease avoidance at the human-animal-environment interface, to a more holistic approach that strives to sustainably balance the health of people, animals, plants and ecosystems.

Narrow approaches may not only miss opportunities for global and local health systems but, initiatives and actions inconsiderate of other disciplines, as well as social, economic and cultural contexts, may result in unforeseen and detrimental consequences (Machalaba et al., 2017). A systems approach helps practitioners conceptualise and evaluate integrated approaches, whilst facilitating learning and comparison (Rüegg et al., 2018b).

The NEOH competencies focus on enabling practitioners, at any level or scale of involvement, to promote and support health system transformation. This could be a One Health government adviser tasked with generating nutritional guidance that would serve public health, animal welfare and the environment or, an international agency interested in surveillance and data sharing for infectious disease outbreaks or pollution monitoring, managing fears over trade restrictions or persecution while advocating for the protection of wildlife, cultural practices and preservation of natural environments. The architecture of the NEOH competencies aims to simplify what can be a complex area, grouping the competencies into the three main areas of: Skills; Values and Attitudes; and Knowledge and Awareness, with several layers underlying each. These are intentionally applicable to stakeholders from various sectors and across all levels. The NEOH competencies differ from those that have gone before in several main areas:

## COMPETENCIES GROUP 1: SKILLS

Uptake of One Health competencies actively promotes a new culture of inter- and transdisciplinary working habits and attitudes (Chiesa et al., 2021; Jerolmack, 2013). Collaboration of individuals, communities and organisations within and between sectors maximises the benefits of shared knowledge and resources, especially relevant in a world with limited resources, whilst avoiding the duplication of logistical efforts (Machalaba et al., 2017; Häsler et al., 2014). Effective communication and collaboration form the basis of essential skills for a One Health practitioner. Removing barriers between and among disciplines to promote mutual cooperation and effective sharing of resources, expertise and skills are essential (Jerolmack, 2013). Collaborative approaches should aim to manage rather than eliminate differences between individuals or communities (Abbas et al., 2022), but historical, institutional and professional silos are often responsible for a lack of genuine horizontal cooperation (Chiesa et al., 2021; Soublis Smyth, 2017; Islam et al., 2020). Meaning, for many, a paradigm shift in governance is required to operationalise One Health. This shift has been seen publicly over the last decade but particularly since 2021. The aspirations of learning institutions should be to provide collaborative and resilient learning environments that will foster the development of minds that can respond to global problems through effective collaboration and transdisciplinarity (Xiang and Lehmann, 2021), including One Health challenges. According to the One Health Commission (OH Commission, 2022) there are over 100 distinct One Health programmes in academic institutions today but a recent review of competencies delivered during One Health Doctoral programmes identified just one course offering study of systems science (Rocheleau et al., 2022). Several universities have, however, included core classes that give their graduates a more impactful skill set, expanding upon the domains and competencies in Table 1 to include environmental economics or conflict resolution for example. While previous domains and competencies mention communication as an important skill, the application of communication appears to be lacking as could be seen with the degree of misinformation (Islam et al., 2020) during the COVID-19 pandemic. To address this gap, One Health courses should also include public speaking and media training.

## COMPETENCIES GROUP 2: VALUES AND ATTITUDE

Values and attitudes as a core competency recognises that political and social assumptions and biases shape the models and policies in which the practitioner will operate (Leach and Scoones, 2013). Recognition of the influences of values and attitudes, both personal and professional, are given greater emphasis within the NEOH proposal than any preceding framework. This is particularly important with increasing calls for decolonisation of science and society for social and environmental justice (de Santos, 2017). Similarly, the NEOH competencies recognise the need for transdisciplinarity, expanding beyond the cross- and multi-disciplinary working featured in earlier frameworks and addressing it's exclusion from current One Health Doctoral training programmes (Rocheleau et al., 2022). Transdisciplinarity, transcending pre-existing disciplinary and knowledge boundaries to synthesise diverse approaches, allows the creation of fundamentally new conceptual frameworks, hypotheses and research strategies (Rüegg et al., 2018a) critical to a successful implementation of One Health.

Transdisciplinary success requires the effort and equitable inclusion of disciplines and, non-academic stakeholders (e.g. Indigenous Peoples representatives and civil society organisations) previously not well represented in One Health. Previous commentators have noted that research and policy narratives can suggest an overly simplistic summary of situations (Leach & Scoones, 2013; Keeley and Scoones, 2003), making inputs from the social sciences (including economics) as well as the arts and humanities essential for the successful integration of stakeholders

**Table 2.** NEOH's nine updated core competencies of One Health: Description and rationale.

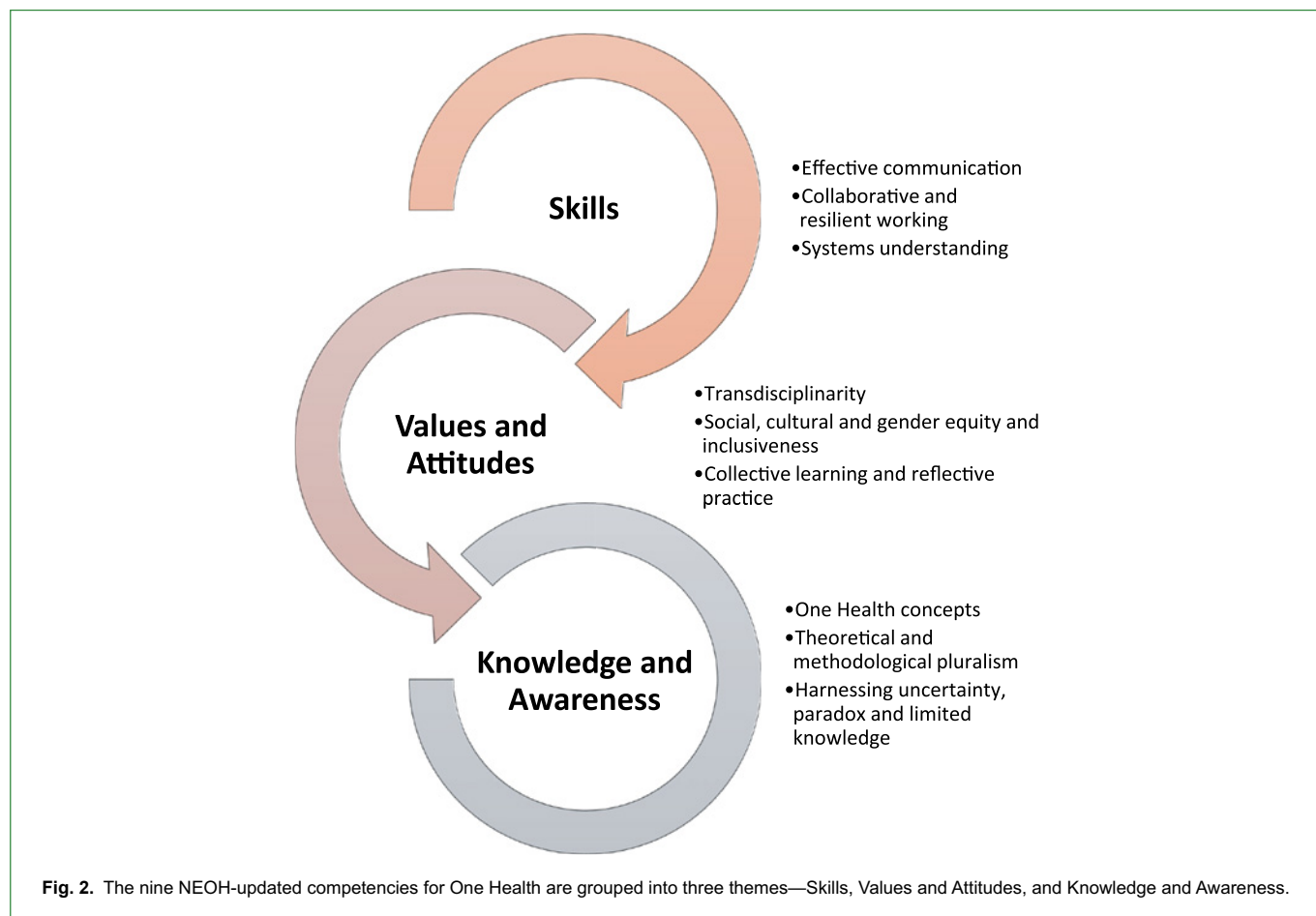| Group | Competency | Description | Rationale |
|---|---|---|---|
| Skills | Effective communication | Engages effectively in respectful and reciprocal communication and partnerships with people from different backgrounds, disciplines, groups in society and sectors. | • The interactive model of communication describes a process where participating parties (i.e., sender and receiver; roles may change in the process) convey meaning in an interactive, verbal and non-verbal, iterative exchange with feedback loops (Archee et al., 2013). In the transaction model of communication, communicators (i.e. people are simultaneously receivers and senders) bring social, relational and cultural contexts into their dialogue and co-generate and negotiate meaning, while also being changed through the experience and forming relationships in the process (Archee et al., 2013). The latter is particularly important in transdisciplinary working in One Health, i.e. when working seamlessly across different groups in society.<br>• Communication disruption occurs through language, physical, emotional or perceptional, cultural, interpersonal and gender barriers (Button & Rossera, 1990; Rani, 2016; Merchant, 2012). In One Health with its working across different sectors, disciplines, and groups in society—often at the level of the system—these barriers are commonly encountered and need to be overcome.<br>• For example:<br>– Language: Sectoral, institutional and disciplinary cultures generate communication gaps through different ways of conceptualising problems, approaches and methods, as well as terminology (Barnett et al., 2020; Buschhardt et al., 2021);<br>– Gender and culture: Gender and cultural differences in political, governance and knowledge systems (e.g., social sciences vs natural sciences) generate complexity in the encoding and decoding of messages, as well as inequities in power, including who is allowed to speak and be listened to (Garnier et al., 2020; Brandão et al., 2021);<br>– Perceptional: Different value and belief systems, experiences and backgrounds create differing perceptions that may hinder communication and restrict One Health progress due to ensuing gradients of power, hierarchy and status (Abbas et al., 2022);<br>• Consequently, a One Health competent person will require awareness of these barriers and the skills (e.g. public speaking, cultural and gender awareness, listening and media training) to overcome them for effective communication. |
| | Collaborative and resilient working | Able to collaborate with One Health partners from diverse backgrounds to reach common understanding and cohesive goals. Treating others with courtesy, sensitivity, and respect. Rapidly adapts to new information, changing conditions, or unexpected obstacles, manages conflicts, recovers quickly. | • The innate nature of One Health interdisciplinary approaches means we should facilitate personnel and skills from various institutions and backgrounds (Bordier et al., 2019; Errecaborde et al., 2019). Abbas et al. (2022) explain how the resultant collaborations should aim to manage rather than eliminate these differences. This enables each collaborator to choose the form of collaboration that is most relevant to their requirements and it is important that we respect the prerogatives of various collaborators in this regard. However, other scenarios, which are determined by a specific outcome, mean that it is a prerequisite for us to establish a common goal and defined responsibilities for collaborators as this is deemed necessary for network success (Errecaborde et al., 2019).<br>• Given the dynamic nature of many One Health challenges, it is important that approaches chosen have adaptive capacities in order to remain effective and resilient (Abbas et al., 2022). There is a body of literature that indicates that increased adaptive capacity, combined with collaborative governance results in a greater resilience (Duit et al., 2010).<br>• Working with others across disciplines and sectors can generate a wide range of emotions, including negative ones such as feelings of confusion, irritation, or anger, that people need to work through (Fitzgerald and Callard, 2015). Emotional resilience includes the ability to adapt under challenging circumstances, recover from adverse feelings and to react adequately when challenges arise; its importance has already been described for the 'helping professions' (Grant and Kinman, 2014). |
| | Systems understanding | Understands and studies the interconnections between humans, animals, plants and ecosystems, and how they influence each other dynamically; manages boundaries, across scales/levels and identifies stakeholders. Approaches situations (including team management and project design) with systems thinking, i.e. identifying relevant elements, their relationships and interactions, recognising patterns, conducting analysis across scales, to understand the problem's dynamic and relevant level of analysis according to emergent properties. | • One Health recognises and emphasises the tight interconnections between health of all living beings within the environment they share. From this starting point, health appears as a dynamic property emerging from multiple interactions at different time scales within complex adaptive systems (CAS). Indeed, all life on Earth appears to evolve through four stages in adaptive cycles: release, reorganisation, exploitation and conservation (Ellaway et al., 2017). Because CAS are characterised by the emergence of new properties, which cannot be derived from the interacting parts, and self-organisation (Capra and Luisi, 2012), they cannot be fully known, nor fully understood and forecasted, but only partially modelled. Hence, the One Health competent person will have to understand and investigate reality as a system. Systems thinking is an umbrella term to designate a variety of ways to model, understand and act in CAS (Hester and Adams, 2017).<br>• The basic implementation of systems thinking rests on the identification and selection of relevant elements, relationships and interactions to account for the dynamics and set boundaries according to the needs of analysis and action. Thus, OH-competent persons are equipped to identify temporal and spatial patterns in a wide set of CAS and contexts, which then help uncover the underlying structures and mechanisms (Wallace et al., 2015). System thinking recognises the perpetual change of CAS and deals with it by continuously moving boundaries and shifting between stakeholders' perspectives (human and non-human) in order to develop a more comprehensive understanding of an evolving issue. This expands also to teams and projects where the use of a systems thinking mindset (Peters, 2014) is encouraged. |

*Continued*

| Values and Attitudes | Transdisciplinarity | Moves beyond disciplinary and sectoral boundaries, works seamlessly across different groups in in society, and works towards solutions collectively. | • Literature identifies seven key characteristics of transdisciplinarity, with their relative emphasis varying between schools of thought. These can be summarised as relating to unity of knowledge (knowledge integration) and social engagement (transformations) (Sankaran et al., 2010). <br> • Key values and attitudes to accomplish successful transdisciplinary work include: <br> – A generalist perspective that recognises problem complexity, diversity of perspectives, complementarities in different bodies and forms of knowledge and an ability to conceptually link these (Lawrence et al., 2022; Hitziger et al., 2018); <br> – Reflexivity as a pre-condition for mutual learning and overcoming communicative, cultural, social or other barriers (including conflict) and power differentials (Pohl and Hardon, 2008); <br> – Interest and experience to personally build interdisciplinary, cross-sectoral and intercultural experiences (enactive learning, side changes, participatory research, becoming a bridge person) (Berger-González et al., 2015); <br> – The ability to liaise with all groups in society, and to organise, facilitate and lead collaborative work, often in non-hierarchical settings (Scholz and Tietje, 2002); <br> – An ability and willingness to counter traditional academic and societal training and success criteria, where the pull back towards "the silo" or the disciplinary academic work is a strong one, and where transdisciplinary research and innovation can be viewed as less efficient for achieving specific goals, even though students and professionals are typically taught to conduct their work with maximal efficiency and are rewarded for doing so (Hitziger et al., 2017). |
| | Social, cultural and gender equity and inclusiveness | Understands and is sensitive to equity and justice in human terms and across animal and plant species and the environment. Acknowledges and incorporates gender and culture considerations. Shows integrity, behaving in an honest, fair and ethical manner with inclusiveness and humility. Acknowledges that we are part of nature. | • Equity and inclusiveness in One Health implies that there is no discrimination based on gender, sex, culture, age or physical ability in the rights to accessing natural resources and landscapes, land tenure, nutritious and diverse food, drinking water, clean air, clean energy, healthcare and education, that we consider that we are part of nature (Garnier et al., 2020), and that people, animals, plants, and the environment all have their own right to health. A competence with an inclusive and biocentric perspective helps overcome barriers encountered in the One Health space, such as: <br> – A human-centered perspective on nature and health by most citizens, including the majority of scientists, contributing to, for example, the extinction and climate crises (Yeung et al., 2021); <br> – Gender discrimination at all levels of society, including decision-making institutions, contributing to, for example, uneven burden of diseases throughout society (Washington et al., 2021); <br> – Cultural discrimination, resulting in the violation of human rights of Indigenous Peoples, ethnic minorities and refugees (Joe et al., 2020). <br> – A view of society as a homogenous group, rejecting individuals that are "different", and thus neglect, ignore and repress their needs, opinions and aspirations (Montag et al., 2021). <br> – A view that humans will be able to solve the current and interconnected health, environmental and climate crises through novel technologies while ignoring their deep social drivers anchored in inequity (Tilly, 2007). |
| | Collective learning and reflective practice | Demonstrates reflective practice, assesses and recognises own values and knowledge, being a humble and active continual learner. | • Reflective practices and the humble implementation process used in One Health approaches mean that continual learning, including enhancement of knowledge and capabilities, should incrementally be acquired from each new One Health experience. Taking advantage of opportunities to grow, but also raising awareness of ambiguities and uncertainty: thus the need for lifelong learning. Some One Health projects have institutionalised self-reflective processes as part of their assessment processes, and this is to be commended to drive future changes in collective learning and practice (McLaren and Markusson, 2020). Some One Health experiences may only create small learning opportunities, but they provoke incremental changes in behaviour, developing and re-adjusting routines for different circumstances. <br> • An appropriate environment is necessary for lifelong learning, and this may be a place of work, but external opportunities such as from learning organisations, as well as formal and informal self-development resources are also available (e.g. online). The learning environment should provide learners with an arena in which they can capitalise on their strengths and compensate for and improve upon their weaknesses. The availability of learning environments differs for organisations, and so competences must be actively considered and acquired by each individual learner but can be facilitated by a community (organisational) ethos of self-reflection in lifelong learning (Unwin et al., 2021). <br> • Reflective practice should include understanding the situation in detail (what, where and with whom); how it made one feel; why did the situation play out as it did; what could be done differently (critically reviewing the situation to identify learning gaps and assumptions, and develop future insights); and from these, exploring opportunities to develop, creating an action plan for acquiring the new learning and thereafter reintegrating the enhanced knowledge and capability into future practice (London, 2011). |

**Table 2.** Continued.

| Group | Competency | Description | Rationale |
|---|---|---|---|
| Knowledge and Awareness | One Health concepts | Knows and uses systematically and consistently different One Health theories, frameworks and methods. | • Since its first appearance in the medical and scientific literature in the early 2000s, One Health has been attributed many definitions and evolved from descriptions of a "mindset" or "way of thinking" to an approach informed and underpinned by theory and evidence (Gibbs, 2014; Zinsstag et al., 2010). These span theories, frameworks and methods such as collaboration and communication (Zinsstag et al., 2010), transdisciplinarity (Assmuth et al., 2020) and collective learning and systems thinking (Rüegg et al., 2018a). There is now also a growing body of One Health economic literature that explores the value of One Health at the human–animal–plant-environment interface, as well as economic paradigms supporting a systems approach to One Health (Machalaba et al., 2017; Bernstein et al., 2022). This is particularly important given the influence of economics on policy-making and behaviour. Also, recognising socio-economic dynamics can contribute to the successful messaging of One Health issues (Chan, 2014).<br>• The body of knowledge on One Health, as well as frameworks, concepts and methods for practicing One Health has been constantly growing and evolving, as a reflection of the ever-changing nature of complex health problems and new perspectives gained. In line with learning in disciplines, knowledge of these definitions, theories, frameworks and methods can allow the One Health practitioner to make an informed choice on the school of thought to apply and implement in One Health activities, justified by nuanced knowledge and based on evidence. |
| | Theoretical and methodological pluralism[a] | Understands, applies and combines knowledge, theories and ideas of multiple sciences. Acknowledges and can navigate across different epistemic and ontological standpoints and knowledge systems, including local and indigenous knowledge. | • One Health brings together theories, knowledge and ideas from a range of disciplines and stakeholders. Thus, an OH competent practitioner must be cognisant of their fundamental elements: ontology, referring to the reality that researchers can acquire knowledge on; epistemology being how that knowledge is created; and how philosophical perspective influences the choice of action taken (Rüegg et al., 2018b; Moon & Blackman, 2014). This understanding will enable the moderation of knowledge integration and collaboration across the plurality of theories and methods, and most importantly, foster their co-existence.<br>• In doing so, this enhances and clarifies a conscious understanding of the relationship(s) between truth and model(s) or belief(s), and an appreciation of legitimacy by the processes of reasoning applied to the knowledge e.g. logical or intuitive (Monteiro et al., 2018). For example, knowledge generated by natural scientific research as a way of understanding reality could be an example of positivism as an epistemological approach. In contrast, indigenous knowledge may also be empirical but extends beyond objective observation, to incorporate culturally or geographically context-specific experiences or values (Mistry, 2009). This being an example of interpretivism.<br>• It is important for One Health professionals to bring together information and knowledge from many sources and disciplines to increase system understanding and better inform decision-making. Practitioners should therefore be able to facilitate the synthesis of evidence in a rigorous, concise and unbiased way, making it inclusive, transparent and accessible to stakeholders and decision-makers (Donnelly et al., 2018). |
| | Harnessing uncertainty, paradox and limited knowledge | Understands, considers and manages effectively that One Health challenges are complex, often wicked problems, for which the knowledge base is incomplete, contains a high level of uncertainty and potential incommensurabilities. Is aware and embraces that we have limited capacity to intervene in certain processes, and may act despite paradox, ambiguity and/or uncertainty. | • One Health challenges are typically wicked problem because health is a social construct with diverse stakeholders understanding it differently. Such challenges are constellations of problems that are linked within unique contexts, often without clear boundaries in time and space. An implicit request of One Health is to ensure health equity across species and generations (Rüegg et al., 2017; Stephen & Oura, 2021). One Health challenges are not simply health problems. They are often deeply complex social problems that sit across and between different government departments, disciplines, and values. Consequently, there are no technical solutions to it, but they require people to match their mindsets and behaviours to the challenge of working in complex systems.<br>• Due to the uniqueness of One Health challenges, data is often unavailable or only partially valid for the specific case. Time constraints imply that decisions to act need not be taken before a satisfactory database is available. A One Health competent person will need to be able to facilitate the trade-off between timely action and a decision base that is acceptable to all stakeholders. An ability to deal with uncertainty and ambiguity is also a central entrepreneurial competency and can be linked to entrepreneurial skills development (Peschl et al., 2021).<br>• The multiple perspectives on a One Health challenge arise from the diversity of stakeholders. To facilitate the circumstances that enable health-promoting decisions and convergence towards synergistic actions, a constructivist epistemological position is most useful (Harrison et al., 2019). This also philosophically aligns the social dimension of implementing a One Health approach with the One Health concepts outlined above and underpins that our knowledge remains incomplete. It requires that a One Health competent person is able to gain a meta-perspective on the challenge and recognise the potential(s) for emerging knowledge and solutions arising from the interaction of different viewpoints, while acknowledging and respecting that some positions are incommensurable. |

[a]Definition of Pluralism (Cambridge Dictionary): The existence of different types of people, who have different beliefs and opinions, within the same society.

**Skills**
- Effective communication
- Collaborative and resilient working
- Systems understanding

**Values and Attitudes**
- Transdisciplinarity
- Social, cultural and gender equity and inclusiveness
- Collective learning and reflective practice

**Knowledge and Awareness**
- One Health concepts
- Theoretical and methodological pluralism
- Harnessing uncertainty, paradox and limited knowledge

**Fig. 2.** The nine NEOH-updated competencies for One Health are grouped into three themes—Skills, Values and Attitudes, and Knowledge and Awareness.

in the fair and ethical manner demanded by our approach. The OHHLEP also directly acknowledged the current lack of social and behavioural science expertise which is required to address critical socio-cultural aspects of One Health implementation (OHHLEP, 2021).

## COMPETENCIES GROUP 3: KNOWLEDGE AND AWARENESS

To enable better participation, Binot et al. (2015) advocated for flexible participatory approaches in One Health, enabling relevant stakeholders to be identified and included in line with their own objectives. The NEOH-updated competencies also promote an adaptive approach, better equipping the practitioner for a complex reality where there may be changing information or conditions, unexpected obstacles or, differences in priorities between stakeholders. A competent One Health professional should be able to manage these often-unpredictable features of health system interventions, recovering quickly and managing trade-offs including (potential) conflicts. An awareness that health systems are rarely fully understood, with much knowledge used being subjective to some degree, for example, according to the perspective of the knowledge holder. It is important that the practitioner understands the ambiguity, paradox and uncertainty that can exist in complex health systems and feels able to address the seeming 'wicked problems' that can exist in One Health.

The updated NEOH competencies more explicitly promote familiarity with the multiple One Health concepts and scholarly activity as well as an appreciation for methodologies from across biological, social, economic and political sciences or from systems thinking. Recognising the importance of One Health in conjunction with subject-specific expertise and further emphasising that One Health should be considered a collaborative, transdisciplinary approach to health and not an isolated discipline in its own right.

A major criticism of One Health is the domination by institutional Global North initiatives with a lack of space for alternative local knowledge and knowledge practices (Galaz et al., 2015; Keune et al., 2017). Networks should not be limited to scientific experts, but open to all, local individuals and communities, grass root organisations, practitioners and policy experts, thus promoting awareness of global health perspectives in locally applicable scenarios. Our updated competencies better incorporate important principles around equity, diversity and inclusion in health and recognition of different forms of knowledge—such as indigenous knowledge. Similarly, the competencies are themselves designed to be inclusive and apply to a range of audiences, from academics and clinicians to international or community organisations. The integration of knowledge across sectors, disciplines and stakeholders is key, but it is important that this integration capacity is sustained beyond the initial planning and implementation stages. It is especially important to ensure integration continues into the evaluation stage, feeding back into policy formulations (Hitziger et al., 2021).

## LIMITATIONS

Our review has been limited to the examination of previous frameworks specifically produced for One Health. However, there has been a gradual convergence of One Health concepts with the parallel movements of Ecohealth and Planetary Health (Zinsstag, 2012). Hence, there may be relevant previous competencies produced under these labels that have not been included in our analysis. However, even though our competencies have been presented for One Health, the systems-based definition underlying their development, makes them applicable across any integrated approach to health. It can be beneficial to unify and harmonise approaches where possible without losing the diversity of participation and perspective that brings much value to the

approach. There has been an increase in the use of the term One Health in the literature associated with the likely zoonotic origins of the SARS-CoV-2 outbreak. One Health has now been referred to by the United Nations and the Quadripartite, the World Bank (Berthe et al., 2018), G7(G7 CARBIS BAY HEALTH DECLARATION, 2021), Paris Peace Forum[b], African Centre for Disease Control (Framework for One Health Practice in National Public Health Institutes—Africa CDC, 2022) alongside many national bodies. It has been referred to as critical in the fight against Antimicrobial resistance, neglected tropical diseases and climate change (Ending the Neglect to Attain the Sustainable Development Goals., 2022; Van Puyvelde et al., 2018). Similarly in the last few years, public educational efforts including those focused on teaching One Health to children and adults at the grass-roots level (while improving public engagement skills of One Health trainees) have been creating a global One Health educational movement (Jane Goodall's Roots and Shoots, n.d.; One Health Lessons n.d.).

*One Health in Education* Teaching for core competencies, and not only for knowledge, is key in One Health curricula. The success of any One Health framework depends on adoption from local to global scales, underpinned by appropriate access to resources and knowledge (Lee and Brumme, 2013). Many educational institutions are now engaging with One Health but are challenged by historic structures and learning outcomes that may not be easily modified to deliver competency-based skills. Togami et al., (2018) addressed this with a step-by-step approach for academic program administrators. There may also be diversity in how One Health is interpreted and taught, making unifying the movement in line with the OHHLEP definition more difficult and failing to deliver a consistency of what it means to be a One Health competent professional. Standardisation within education frameworks and degree curricula will be essential (Togami et al., 2018).

Innovative approaches should be sought to enable students from across health-related disciplines and beyond, to acquire training on One Health competencies. One Health professionals also benefit from a background in subject-specific expertise, with One Health competencies layered on top to provide the links that bring expertise together. The transferable nature of many One Health competencies e.g. 'big picture thinking', mean they have value across interdisciplinary fields, whether the individual goes on to formally practice in One Health or not. Additionally, in delivering competency-based training, the process itself can help to enhance some of the required skills e.g. open-mindedness and self-reflection. When teaching competencies, formative success is linked to the ability of the student to learn from experiences and to use such learning to impact their own professional and personal development (European Commission, 2019). Such learning can be achieved using "immersive" teaching environments, e.g. field trips, which promote training in context, stimulating the critical skills of students and encouraging knowledge transfer (Mor et al., 2018). Other effective strategies are 'problem-based learning', where the student autonomously proposes solutions to a set problem which can be useful to develop lifelong learning skills and help students relate knowledge to solve problems independently (Hmelo-Silver, 2004). In all cases, acquiring OH competencies is a social process, calling for mutual and shared learning. These questions or even blurs the border between learning and teaching, with all participants of a program intervening in the process as equals (Sidikou et al., 2021).

There are also opportunities to address the barrier of professional siloes or translation of disciplinary languages during training (Larsen, 2021) e.g. with mixed discipline One Health courses.

[b]Director-General of the FAO, Dr. QU Dongyu, closed his speech at the November 2020 Paris Peace Forum with the wish that all join him in proclaiming *"All for One health, and One Health for All; since United we stand, but divided we fall"*.

## Conclusion

The updated competencies from NEOH can be used to evaluate and enhance current curricula, create new ones, or inform professional training programs at all levels, including students, university teaching staff or government officials as well as continual professional development for frontline health practitioners and policymakers.

Although there are some differences in how One Health has been interpreted across different sectors and disciplines historically, the broad OHHLEP definition has been well received and we believe the NEOH competencies aligns with its tenets and will help with the successful implementation of One Health programmes (FAO et al. 2022).

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# References

Abbas, S.S., Shorten, T., and Rushton, J. (2022) Meanings and mechanisms of One Health partnerships: Insights from a critical review of literature on cross-government collaborations. *Health Policy and Planning,* 37(3), 385–399. DOI: 10.1093/heapol/czab134

Archee, R., Gurney, M., and Mohan, T. (2013) Communicating as professionals. *Victoria, South Melbourne*.

Assmuth, T., Chen, X., Degeling, C., Haahtela, T., Irvine, K.N., et al. (2020) Integrative concepts and practices of health in transdisciplinary social ecology. *Socio-Ecological Practice Research*, 2(1), 71–90. DOI: 10.1007/s42532-019-00038-y

Barnett, T., Pfeiffer, D.U., Ahasanul Hoque, M.D., Giasuddin, M., Flora, M.S., et al. (2020) Practising co-production and interdisciplinarity: Challenges and implications for one health research. *Preventive Veterinary Medicine*, 177, 104949. Available at: https://www.sciencedirect.com/science/article/pii/S0167587719307615

Berger-González, M., Stauffacher, M., Zinsstag, J., Edwards, P., and Krütli, P. (2015) Transdisciplinary research on cancer-healing systems between biomedicine and the maya of guatemala: A tool for reciprocal reflexivity in a multi-epistemological setting. *Qualitative Health Research,* 26(1), 77–91. DOI: 10.1177/1049732315617478

Bernstein, A.S., Ando, A.W., Loch-Temzelides, T., Vale, M.M., Li, B.V., et al. (2022) The costs and benefits of primary prevention of zoonotic pandemics. *Science Advances*, 8(5), 4183. DOI: 10.1126/sciadv.abl4183

Berthe, F.C.J., Bouley, T., Karesh, W.B., Le Gall, F.G., Machalaba, C.C., et al. (2018) One Health: Operational framework for strengthening human, animal and environmental public health systems at their interface. Washington. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/703711517234402168/operational-framework-for-strengthening-human-animal-and-environmental-public-health-systems-at-their-interface

Binot, A., Duboz, R., Promburom, P., Phimpraphai, W., Cappelle, J., et al. (2015) A framework to promote collective action within the One Health community of practice: Using participatory modelling to enable interdisciplinary, cross-sectoral and multi-level integration. *One Health*, 1, 44–48. Available at: https://pubmed.ncbi.nlm.nih.gov/28616464

Bordier, M., Delavenne, C., Nguyen, D.T.T., Goutard, F.L., and Hendrikx, P. (2019) One Health surveillance: A matrix to evaluate multisectoral collaboration. *Frontiers in Veterinary Science,* 6, 109. DOI: 10.3389/fvets.2019.00109

Brandão, A.P.D., Sussai, S., Germine, J.A.D.L., Eltz, D.D., and Araújo, A. (2021) Social sciences in One Health: Insights From multiple worlds perspectives on the dam rupture in Brumadinho-Brazil. *Frontiers in Public Health,* 9, 649355. DOI: 10.3389/fpubh.2021.649355

Buschhardt, T., Günther, T., Skjerdal, T., Torpdahl, M., Gethmann, J., et al. (2021) A one health glossary to support communication and information exchange between the human health, animal health and food safety sectors. *One Health*, 13, 100263. Available at: https://www.sciencedirect.com/science/article/pii/S2352771421000537

Button, K., and Rossera, F. (1990) Barriers to communication. *The Annals of Regional Science,* 24(4), 337–357. DOI: 10.1007/BF01580478.

Capra, F., and Luisi, P.L. (2012) The systems view of life: A unifying vision. *The Systems View of Life,* 1–498. Available at: https://www.cambridge.org/core/books/systems-view-of-life/35186BA5B12161E469C4224B6076ADFE

CDC. (2010) Operationalizing "One Health": A policy perspective—Taking stock and shaping an implementation roadmap.

Chan, K. (2014) Chapter 19. Economics and global health. In: *Understanding Global Health*. Lange: McGraw-Hill Education.

Chiesa, F., Tomassone, L., Savic, S., Bellato, A., Mihalca, A.D., et al. (2021) A survey on One Health perception and experiences in Europe and neighboring areas. *Frontiers in Public Health*, 9, 609949. DOI: 10.3389/fpubh.2021.609949

de Santos, B.S. (2017) Decolonising the university: The challenge of deep cognitive justice. 1st ed. Vol. 1. Cambridge Scholars Publishing, Newcastle upon Tyne, England, p. 481.

Donnelly, C.A., Boyd, I., Campbell, P., Craig, C., Vallance, P., et al. (2018) Four principles to make evidence synthesis more useful for policy. *Nature*, 558(7710):361–364. Available at: https://EconPapers.repec.org/RePEc:nat:nature:v:558:y:2018:i:7710:d:10.1038_d41586-018-05414-4

Duit, A., Galaz, V., Eckerberg, K., and Ebbesson, J. (2010) Governance, complexity, and resilience. *Global Environmental Change,* 20(3), 363–368. Available at: https://www.sciencedirect.com/science/article/pii/S095937801000035X

Ellaway, R.H., Bates, J., and Teunissen, P.W. (2017) Ecological theories of systems and contextual change in medical education. *Medical Education*, 51(12), 1250–1259.

Ending the Neglect to Attain the Sustainable Development Goals. (2022) One health: Approach for action against neglected tropical diseases 2021–2030. Available at: https://www.who.int/publications/i/item/9789240042414 (accessed March 1, 2022).

Errecaborde, K.M., Macy, K.W., Pekol, A., Perez, S., O'Brien, M.K., et al. (2019) Factors that enable effective One Health collaborations—A scoping review of the literature. *PLoS One*, 14(12), e0224660. DOI: 10.1371/journal.pone.0224660

European Commission. (2019) Key Competences for Lifelong Learning. Directorate-General for Education, Youth, Sport and Culture.

FAO, UNEP WHO, and WOAH. (2022) Global Plan of Action on One Health. Towards a More Comprehensive One Health, Approach to Global Health Threats at the Human-Animal-Environment Interface. Rome. DOI: 10.4060/cc2289en

Fitzgerald, D., and Callard, F. (2015) Chapter 7, feeling fuzzy: The emotional life of interdisciplinary collaboration. In: *Rethinking Interdisciplinarity across the Social Sciences and Neurosciences.* Basingstoke, UK: Palgrave Macmillan.

Framework for One Health Practice in National Public Health Institutes—Africa CDC. (2022) Available at: https://africacdc.org/download/framework-for-one-health-practice-in-national-public-health-institutes/ (accessed March 1, 2022).

Frankson, R., Hueston, W., Christian, K., Olson, D., Lee, M., et al. (2016) One Health core competency domains. *Frontiers in Public Health*, 4, 192. doi: 10.3389/fpubh.2016.0019.

G7 CARBIS BAY HEALTH DECLARATION. In Cardis Bay, Cornwall, UK; 2021. Available at: https://www.g7uk.org/wp-content/uploads/2021/06/G7-Carbis-Bay-Health-Declaration-PDF-389KB-4-Pages.pdf (accessed March 1, 2021).

Galaz, V., Leach, M., Scoones, I., Stein, C., and Health, O. (2015) The political economy of One Health research and policy. Available at: www.steps-centre.org/publications

Garnier, J., Savic, S., Boriani, E., Bagnol, B., Häsler, B., et al. (2020) Helping to heal nature and ourselves through human-rights-based and gender-responsive One Health. *One Health Outlook*, 2(1), 22. DOI: 10.1186/s42522-020-00029-0

Gibbs, E.P.J. (2014) The evolution of one health: A decade of progress and challenges for the future. *Veterinary Record*, 174(4), 85–91.

Grant, L., and Kinman, G. (2014) Emotional resilience in the helping professions and how it can be enhanced. *Health and Social Care Education*, 3(1), 23–34. DOI: 10.11120/hsce.2014.00040

Hamilton, K., Nutter, F., Olson, D.K., and Steele, J. (2015) USAID RESPOND project's global one health core competencies and one health modules. *Annals of Global Health,* 81(1), 150.

Harrison, S., Kivuti-Bitok, L., Macmillan, A., and Priest, P. (2019) EcoHealth and One Health: A theory-focused review in response to calls for convergence. *Environment International,* 132, 105058. Available at: https://www.sciencedirect.com/science/article/pii/S0160412019305409

Häsler, B., Cornelsen, L., Bennani, H., and Rushton, J. (2014) A review of the metrics for One Health benefits. *Revue Scientifique et Technique,* 33, 453–464.

Hester, P.T., and Adams, K.M. (2017) *Systemic Decision Making*. Cham, Switzerland: Springer.

Hitziger, M., Berger Gonzalez, M., Gharzouzi, E., Ochaíta Santizo, D., Solis Miranda, R., et al. (2017) Patient-centered boundary mechanisms to foster intercultural partnerships in health care: A case study in Guatemala.

*Journal of Ethnobiology and Ethnomedicine,* 13(1), 44. DOI: 10.1186/s13002-017-0170-y

Hitziger, M., Esposito, R., Canali, M., Aragrande, M., Häsler, B., et al. (2018) Knowledge integration in one health policy formulation, implementation and evaluation. *Bulletin of the World Health Organization,* 96(3), 211–218.

Hitziger, M., Berezowski, J., Dürr, S., Falzon, L.C., Léchenne, M., et al. (2021) System thinking and citizen participation is still missing in One Health Initiatives—Lessons From fifteen evaluations. *Frontiers in Public Health*, 9. DOI: 10.3389/fpubh.2021.653398

Hmelo-Silver, C.E. (2004) Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235–266. DOI: 10.1023/B:EDPR.0000034022.16470.f3

Islam, M.S., Sarkar, T., Khan, S.H., et al. (2020) COVID-19–Related infodemic and its impact on public health: A global social media analysis. *The American Journal of Tropical Medicine and Hygiene*, 103(4), 1621–1629. DOI: 10.4269/ajtmh.20-0812

Jane Goodall's Roots and Shoots. (n.d.) Jane Goodall Institute UK. Available at: https://www.rootsnshoots.org.uk/ (accessed 16 December 2022).

Jerolmack, C. (2013) Who's worried about turkeys? How "organisational silos" impede zoonotic disease surveillance. *Sociology of Health & Illness*, 35(2), 200–212.

Joe, W., Kumar, A., Rajpal, S., Mishra, U.S., and Subramanian, S.V. (2020) Equal risk, unequal burden? Gender differentials in COVID-19 mortality in India. *Journal of Global Health Science*, 2(1), e17. DOI: 10.35500/jghs.2020.2.e17

Keeley, J., and Scoones, I. (2003) *Understanding Environmental Policy Processes: Cases from Africa*. New York: Taylor & Francis.

Keune, H., Flandroy, L., Thys, S., de Regge, N., Mori, M., et al. (2017) The need for European OneHealth/EcoHealth networks. *Archives of Public Health*, 75(1), 64. DOI: 10.1186/s13690-017-0232-6

Khan, M.S., Rothman-Ostrow, P., Spencer, J., Hasan, N., Sabirovic, M., et al. (2018) The growth and strategic functioning of One Health networks: A systematic analysis. *Lancet Planet Health*, 2(6), e264–73.

Larsen, R.J. (2021) Shared curricula and competencies in one health and health professions education. *Medical Science Educator*, 31(1), 249–252. DOI: 10.1007/s40670-020-01140-7

Lawrence, M.G., Williams, S., Nanz, P., and Renn, O. (2022) Characteristics, potentials, and challenges of transdisciplinary research. *One Earth*, 5(1), 44–61. DOI: 10.1016/j.oneear.2021.12.010

Leach, M., and Scoones, I. (2013) The social and political lives of zoonotic disease models: Narratives, science and policy. *Social Science & Medicine*, 88, 10–17.

Lee, K., and Brumme, Z.L. (2013) Operationalizing the One Health approach: The global governance challenges. *Health Policy and Planning,* 28(7), 778–785. DOI: 10.1093/heapol/czs127

London, M. (2011) *The Oxford Handbook of Lifelong Learning*. Oxford: Oxford University Press.

Machalaba, C., Smith, K.M., Awada, L., Berry, K., Berthe, F., et al. (2017) One Health economics to confront disease threats. Vol. 111, *Transactions of the Royal Society of Tropical Medicine and Hygiene*. Oxford University Press, Oxford, UK, p. 235–237.

McLaren, D., and Markusson, N. (2020) The co-evolution of technological promises, modelling, policies and climate change targets. *Nature Climate Change*, 10(5), 392–397. DOI: 10.1038/s41558-020-0740-1

Merchant, K. (2012) How men and women differ: Gender differences in communication styles, influence tactics, and leadership styles. *CMC Senior Theses.* Available at: https://scholarship.claremont.edu/cmc_theses/513 [accessed: Feb 28, 2022].

Mistry, J. (2009) Indigenous knowledges. In: Kitchin, R., Thrift, N. (eds.) *International Encyclopedia of Human Geography*. Oxford: Elsevier, p. 371–376. Available at: https://www.sciencedirect.com/science/article/pii/B9780080449104001012

Montag, D., Barboza, M., Cauper, L., Brehaut, I., Alva, I., et al. (2021) Healthcare of indigenous amazonian peoples in response to COVID-19: Marginality, discrimination and revaluation of ancestral knowledge in Ucayali, Peru. *BMJ Global Health,* 6(1), e004479. Available at: http://gh.bmj.com/content/6/1/e004479.abstract

Monteiro, S., Norman, G., and Sherbino, J. (2018) The 3 faces of clinical reasoning: Epistemological explorations of disparate error reduction strategies. *Journal of Evaluation in Clinical Practice*, 24(3), 666–673. DOI: 10.1111/jep.12907

Moon, K., and Blackman, D. (2014) A guide to understanding social science research for natural scientists. *Conservation Biology,* 28(5), 1167–1177. DOI: 10.1111/cobi.12326

Mor, S.M., Norris, J.M., Bosward, K.L., Toribio, J.A.L.M.L., Ward, M.P., et al. (2018) One health in our backyard: Design and evaluation of an experiential learning experience for veterinary medical students. *One Health*, 5, 57–64. Available at: https://www.sciencedirect.com/science/article/pii/S2352771418300119

Mulder, M. (2022) Competence-based vocational and professional education: Bridging the worlds of work and education. Available at: https://books.google.com/books/about/Competence_based_Vocational_and_Professi.html?id=5h4DDQAAQBAJ (accessed: Feb 28, 2022).

OH Commission. (2022) Academic Organizations. Available at: https://www.onehealthcommission.org/en/resources__services/whos_who_in_one_health/academic_organizations/ (accessed March 1, 2022).

OHHLEP. (2021) First Virtual Meeting of the One Health High Level Expert Panel 17-18 May 2021 Note for the Record.

One Health High-Level Expert Panel (OHHLEP), Adisasmito, W.B., Almuhairi, S., Behravesh, C.B., Bilivogui, P., Bukachi, S.A., et al. (2022) One Health: A new definition for a sustainable and healthy future. *PLoS Pathogens*, 18(6), e1010537. DOI: 10.1371/journal.ppat.1010537

One Health Lessons (n.d.) Available at: https://onehealthlessons.org/ (accessed 16 December 2022).

Peschl, H., Deng, C., and Larson, N. (2021) Entrepreneurial thinking: A signature pedagogy for an uncertain 21st century. *The International Journal of Management Education*, 19(1), 100427. DOI: 10.1016/j.ijme.2020.100427

Peters, D.H. (2014) The application of systems thinking in health: why use systems thinking? *Health Research Policy and Systems*, 12(1). Available at: /pmc/articles/PMC4245196/

Pohl, C., and Hardon, G.H. (2008) Methodological challenges of transdisciplinary research. *Natures Sciences Sociétés,* 16, 111–121.

Rani, K.U. (2016) Communication barriers. *Journal of English Language and Literature*, 3(2), 74–76.

Rocheleau, J.P., Aenishaenslin, C., Boisjoly, H., Richard, L., Zarowsky, C., et al. (2022) Clarifying core competencies in One Health doctoral education: The central contribution of systems thinking. *One Earth*, 5(4), 311–315.

Rüegg, S.R., McMahon, B.J., Häsler, B., Esposito, R., Nielsen, L.R., et al. (2017) A blueprint to evaluate One Health. *Frontiers in Public Health*, 5, 20. DOI: 10.3389/fpubh.2017.00020

Rüegg, S.R., Häsler, B., and Zinsstag, J. (2018a) *Integrated Approaches to Health A Handbook for the Evaluation of One Health*. Wageningen, The Netherlands: Wageningen Academic Publishers.

Rüegg, S.R., Nielsen, L.R., Buttigieg, S.C., Santa, M., Aragrande, M., et al. (2018b) A systems approach to evaluate one health initiatives. *Frontiers in Veterinary Science,* 5, 23. DOI: 10.3389/fvets.2018.00023

Salzburg Global Seminar. (2007) New Century, New Challenges, New Dilemmas: The Global Nexus of Animal and Public Health. Salzburg, Austria. Available at: https://www.salzburgglobal.org/multi-year-series/outbreaks/pageId/699

Sankaran, S., Haslett, T., and Sheffield, J. (2010) Systems thinking approaches to address complex issues in project management. In: *Project Management Institute Global Congress 2010—Asia Pacific*. Melbourne, Australia. Available at: https://www.pmi.org/learning/library/systems-thinking-soft-methodology-issues-6912

Scholz, R.W., and Tietje, O. (2002) Embedded case study methods: Integrating quantitative and qualitative knowledge. Thousand Oaks, CA: Sage Publications.

Sidikou, D.I., Irabor, T.J., Bonfoh, B., Binot, A., Faulx, D., et al. (2021) Teaching and learning for change: Analysis of a post-graduate One Health program. *Sustainability Science*, 17(1), 65–80. DOI: 10.1007/s11625-021-01053-3

Soublis Smyth, T. (2017) Transdisciplinary pedagogy: A competency based approach for teachers and students to promote global sustainability. *Journal of Interdisciplinary Studies in Education*, 5(2), 64–72.

Stephen, C., and Oura, C. (2021) Reflections on One Health leadership training needs for the 21st century. *One Health*, 13, 100356. Available at: https://www.sciencedirect.com/science/article/pii/S2352771421001464

Tilly, C. (2007) Poverty and the politics of exclusion. In: Narayan, D., and Petesch, P. (eds.) *Moving out of Poverty: Cross-Disciplinary Perspectives on Mobility*. Washington DC: World Bank, p. 44–75.

Togami, E., Gardy, J.L., Rizzo, D.M., Wilson, M.E., and Mazet, J.A. (2018) Core competencies in One Health education: What are we missing?.

Unwin, S., Commitante, R., Moss, A., Bridges, E., Farmer, K.H., et al. (2021) Evaluating the contribution of a wildlife health capacity building program on orangutan conservation. *American Journal of Primatology*, 84(4–5), e23273.

Van Puyvelde, S., Deborggraeve, S., and Jacobs, J. (2018) Why the antibiotic resistance crisis requires a One Health approach. *The Lancet Infectious Diseases*, 18(2), 132–134. Available at: http://www.thelancet.com/article/S1473309917307041/fulltext

Wallace, R.G., Bergmann, L., Kock, R., Gilbert, M., Hogerwerf, L., et al. (2015) The dawn of Structural One Health: A new science tracking disease emergence along circuits of capital. *Social Science & Medicine*, 129, 68–77. Available at: https://www.sciencedirect.com/science/article/pii/S0277953614006145

Washington, H., Piccolo, J., Gomez-Baggethun, E., Kopnina, H., and Alberro, H. (2021) The trouble with anthropocentric hubris, with examples from conservation. *Conservation*, 1(4), 285–299.

Xiang, D., and Lehmann, L.S. (2021) Confronting the misinformation pandemic. *Health Policy and Technology*, 10(3), 100520. Available at: /pmc/articles/PMC8117478/

Yeung, E., Carlin, L., Sandassie, S., and Jaglal, S. (2021) Transdisciplinary training: What does it take to address today's "wicked problems"? *Innovation and Education,* 3(1), 4. DOI: 10.1186/s42862-021-00011-1

Zinsstag, J. (2012) Convergence of EcoHealth and One Health. *EcoHealth,* 9(4), 371–373. Available at: https://pubmed.ncbi.nlm.nih.gov/23392841

Zinsstag, J., Schelling, E., Waltner-Toews, D., and Tanner, M. (2010) From "one medicine" to "one health" and systemic approaches to health and well-being. *Preventive Veterinary Medicine*, 101(3–4):148–156. Available at: https://pubmed.ncbi.nlm.nih.gov/20832879