One Health: Insights from Organizational & Social, Technology Assessment and Human Factors Perspectives

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Summary

Objectives: To offer diverse but complementary perspectives on how biomedical and health informatics can be informed by and help to achieve the vision of One Health.

Methods: Overview of key considerations and critical discussion of common themes, barriers and opportunities, based on collaborative review by International Medical Informatics Association (IMIA) working group members active in related fields.

Results: Health and care systems are complex sociotechnical systems that need explicit design and implementation strategies to align with the goals of One Health. The evidence-based health informatics paradigm and associated frameworks for evaluation of digital health technologies need to broaden their scope to take full account of the One Health approach. Informatics has specific contributions to make to One Health, for example by improved user experience reducing energy consumption and effective app design enhancing medication adherence.

Conclusions: One Health is inherently intertwined with ergonomic, sociotechnical and evaluation perspectives in biomedical and health informatics. Health is a planetary issue that requires interdisciplinary collaborative action. The theories and principles of biomedical and health informatics offer many opportunities to transform digital health technology to better serve the One Health agenda.

Keywords

One Health; global health; informatics; ergonomics; technology assessment, biomedical

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1 Introduction

One Health is a holistic philosophy about life on this planet: the health of humans, animals and their shared environment is inherently interconnected and interdependent, and requires interdisciplinary thinking and action to address global issues of fundamental importance [1–3]. Why is this relevant for biomedical and health informatics (BMHI) and digital health technology?

As the survey article in this Yearbook discussed [4], there is growing recognition that the One Health approach can lead to progress in vital domains such as antimicrobial stewardship, disease surveillance, population health insights based on FAIR (Findability, Accessibility, Interoperability, and Reuse) principles and environmental monitoring. Biomedical informatics is intrinsic to effective advancement in all these areas, extending the principle that "information is a form of care" [5]. Information systems will have to manage and analyze health-related and care-related data, with an increasing focus on the interrelation of both human and animal populations and individuals and the rest of the biosphere within the physical environment. For humans, this would also include mental health considerations and broader social determinants of health such as education, housing, energy security, diet and employment. The One Health approach has the potential to inform the development and evaluation of harmonized information technology-based strategies for disease detection and prevention as part of a wellness-focused ecosystem. The concept of One Digital Health (ODH) has been developed to highlight this interdependence [6], structured around individual, population and ecosystem perspectives.

Health and care systems are sociotechnical systems. System design for One Health must pay attention to the interactions across system levels (micro, meso and macro). We cannot ignore the complexities of nurturing sociotechnical systems that align with One Health.

The International Medical Informatics Association (IMIA) working groups on Organizational & Social Issues, Technology Assessment & Quality Development, and Human Factors Engineering have collaborated to produce this viewpoint paper about the importance of One Health in our respective fields, and how the methods, conceptual frameworks and research themes of our disciplines can evolve to serve the ambitions of One Health. Each theme offers a distinct lens on One Health and its relationship to biomedical informatics, and we highlight common principles that emerge.

2 How to Approach Organizational and Social Issues in One Digital Health

One Health and ODH clearly entail organizational and social issues (OSI), given the global nature of the problem space and its manifestation at micro, meso and macro scales. A key goal of OSI research is to understand how various organizational and social factors such as workflow, policy, and communication impact digital health technology design and implementation. A core challenge of OSI studies is the enormous range of factors that impact digital health technology uptake and use. Earlier work on OSI and digital health technology identified the need for "bounding" to help us understand the range of concepts and situational factors that impact implementation in a setting or context [7].

ODH adds another dimension to the bigger ecosystem where digital health technology is used by integrating individual health and well-being, population and society, and ecosystem concepts [6]. While this creates added complexity, it does not change the overall goal of wanting to design digital health technology to improve human health and wellbeing.

ODH is a variation on systems thinking, an approach that describes the critical interactions within a health system and does not focus on any one component but rather tries to understand the interactions that exist across system components [8]. We expand on an existing framework for studying OSIs and digital health technology [9] by describing how the framework could enable ODH (Figure 1).

As we pursue ODH, we need to remember that clinical, social, and organizational processes do not change instantaneously, which adds to system complexity. Many of the processes we are trying to digitize, for example team-based care delivery, handovers, and inter-organizational data sharing are evolving processes [9]. ODH introduces a bigger system of processes to integrate, and we must account for process evolution and maturity as part of system design to support ODH.

A key aim of ODH is to improve collaboration across One Health and digital health communities [6]. Collaborative systems thinking is needed to enable the development of collaborative systems. Collaborative systems thinking helps us define the necessary structural and behavioural concepts needed to support collaboration [10]. For example, collaborative competencies such as awareness and common ground are essential building blocks of a collaborative system.

It is an obvious characteristic that health information systems do not work and produce outcomes until they are used by the health professionals. The use of information systems is complex and most often specific to a particular work situation or context. In a sociotechnical approach, work practice is regarded as a network of people, tools, work routines, clinical information systems …etc. An emergency ward, an outpatient clinic or an inpatient ward is regarded as an assembly of humans and artifacts used to deliver patient care. The work of the health professionals is articulated with the functioning of clinical information systems, monitors, and other equipment to care for patients. At the same time, a number of secondary work functions are performed – teaching medical or nursing students, documenting information for quality assurance or participating in clinical research projects. All these elements are constitutive of the work processes. If you could take away just one of these elements the work process could not be performed in the same complex and continuous manner [11]. The single elements cannot be regarded as discrete with predetermined functionalities – they only achieve specific characteristics as a part of a network. A nurse is only a nurse by virtue of the network the person is a part of. Without the artifacts and the colleagues and patients the nurse would not be a nurse. To study OSI in a One Health perspective the specific context of use must be considered. All the significant elements of the work process must be mapped out and analyzed with respect to the integrative issues to create the full picture. From a health care system perspective, it should be noted that each single network in a specific department is also a part of the total health care system, which means we have to be aware of integration issues that enable institutional care for a population in a One Health perspective.

In designing information technology infrastructure, two main types of network connectivity are considered – peer-to-peer or network sharing. Peer-to-peer connectivity is very common in early communication models in health care. For example, it is quite common to have medication systems sending prescriptions from a primary care physician to a specific pharmacy where the patient can go and pick up the medicine. The different socio technical networks involved in a care process are not part of this communication which increases the probability of adverse events. In a network sharing configuration, a prescription or referral will be sent to a central database where all relevant provider as well as the patient can have access to the information. Similar consideration relates to connectivity in One Health perspectives. All the work constitutive elements must be included in the analysis to uncover all aspects of organizational and social issues.

As pointed out by the framework discussed here [9], there is a need for a greater range of diverse methods in studying pre- and post-implementation OSI issues. This holds true particularly in the ODH context. From qualitative methods for initial identification of problems to quantitative methods for outcome evaluation, from methods that analyze positive impact to those dissect root causes of negative results, from methods implemented with consideration of local culture, population, and environment to approaches

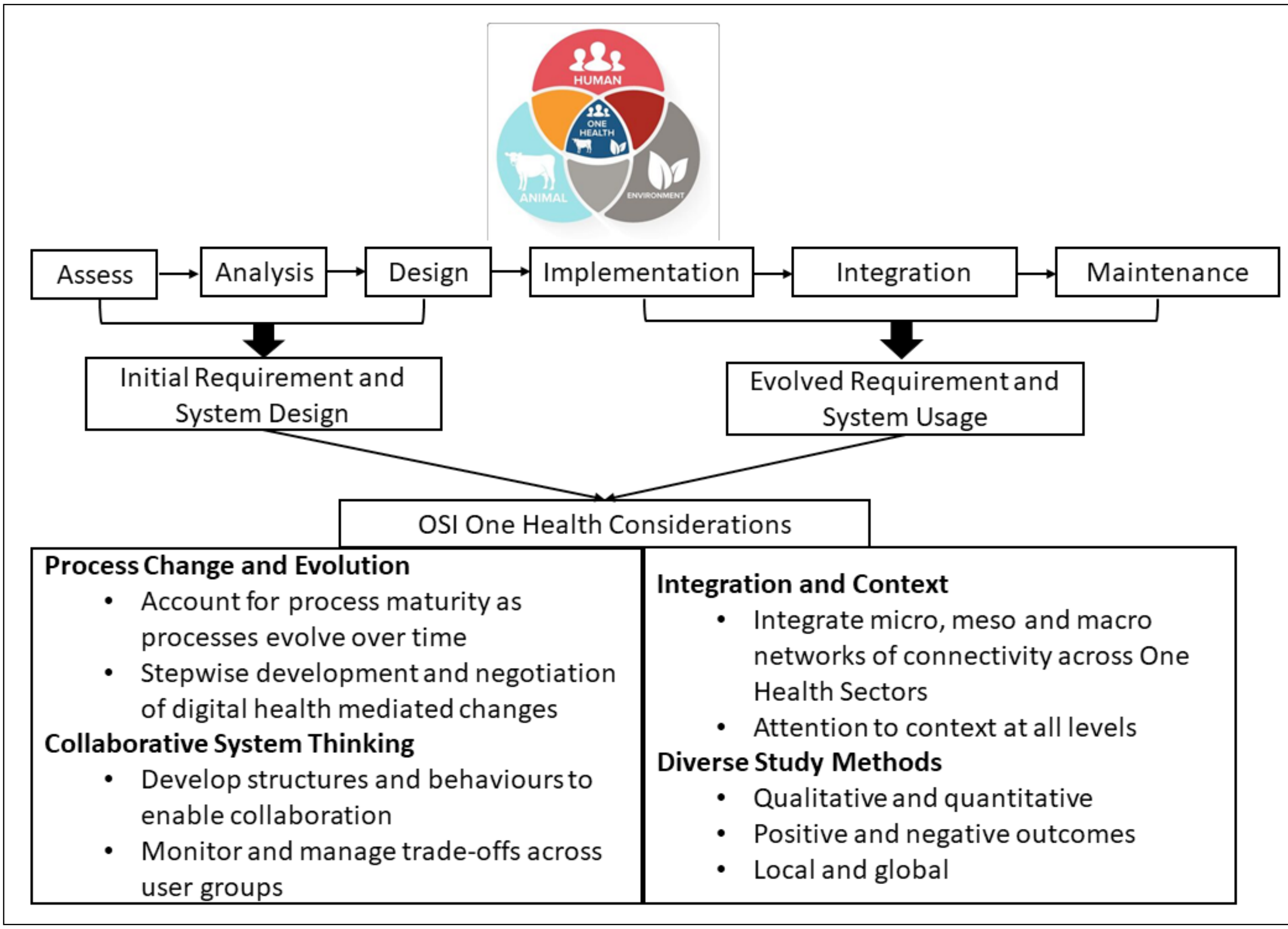

Fig. 1 One Digital Health (ODH) Framework for Organizational and Social Issues (OSI) (adapted from [9])

addressing global ODH issues with generalizability for information interface, exchange, and integration, each of these method categories needs a series of studies on what can be conducted efficiently, effectively and even proactively. For example, a literature search by the authors on quantitative measures for OSI issues yielded limited results, indicating this is an area that still lacks sufficient studies and presents room for improvement. With the increasing volume and dynamically changing nature of ODH data, innovative methods such as clinical simulation testing could be used more widely to play an important role in predicting catastrophic events and their ripple effects in healthcare [12, 13].

3 How the One Health Perspective Informs Evaluation of Digital Health Technology

As described in the introduction to this paper, One Health is a collaborative, multisectoral, and transdisciplinary approach – working at the local, regional, national, and global levels – with the goal of achieving optimal health outcomes by recognizing the interconnection between people, animals, plants, and their shared environment [14, 15]. To effectively address emerging threats such as climate change, biodiversity loss, emergence of new zoonotic diseases potentially leading to global pandemics, food insecurity, and antibiotic resistance, holistic approaches to the evaluation of information systems are needed.

3.1 What Does this Transdisciplinary and Global Perspective on Planet Health Mean for Digital Health Technology Evaluation?

The paradigm of evidence-based health informatics (EBHI) states that decisions related to information systems should be made using appropriate evidence. EBHI is defined as the conscientious, explicit, and judicious use of the current best evidence when making decisions about the introduction and operation of IT in a given healthcare setting [16]. EBHI is especially important since one third of evaluation studies is never published due to a perceived lack of interest from the public [17]. Even when evaluation studies are published, the One Health approach is almost never used to predict and evaluate the impact of the information systems on the environment. For example, in a review of antimicrobial resistance reporting information systems, none of the systems were evaluated in relation to their environmental impact, and only 4 out of 27 included animal data [18]. Therefore, there is a need to incorporate One Health approach into the EBHI paradigm.

3.2 What Makes Evaluation of ODH Challenging?

Digital health technology, and especially ODH, can be considered complex interventions. A complex intervention shows the following attributes: high number of interacting components, high degree of flexibility in customization and processes, numerous user groups and target groups, and various intended outcomes [19]. This is all true for ODH. ODH incorporates a large number of interacting components including reporting, analytics and prediction systems, user interfaces, interoperability standards, decision support, and diverse and heterogeneous data. The number and difficulty of behaviours required by those delivering or receiving the intervention is also high, as ODH attempts to address 'wicked problems' [20] that do not have simple solutions. Groups or organisational levels targeted by the intervention include healthcare and social care providers, public health organizations, payers (whether insurance or taxation based) and environmental protection agencies at local, national, and global levels. To assess ODH, multiple outcomes need to be measured including implementation outcomes (acceptability, adoption, appropriateness, feasibility, fidelity, implementation cost, penetration, and sustainability) [21], health outcomes, process outcomes, and technical outcomes (quality of information, interoperability of data and systems). Finally, ODH must be tailored to the local context and requires a great degree of flexibility or tailoring.

3.3 How Could Evaluation of One Health Information Systems Be Conceptualized?

A theoretical perspective that could help to conceptualize the evaluation of ODH is logic models. Logic models help to understand how and under which circumstances complex interventions such as health information technologies (IT) contribute to certain outcomes. Logic models describe the causal pathways by which the intervention leads to outcomes, and any factors that may modify intervention effects [22]. Logic models typically distinguish three types of impact: (i) output, describing the direct output of a technology (*e.g.*, access to data and information); (ii) outcome, describing what the effect of this output (*e.g.*, better decision-making for the doctor); and (iii) impact, describing the long-term societal impact of the technology. Research has developed methodologies for evaluating outputs and outcomes of health IT [23]. However, less emphasis has been put on evaluating the impact of health IT.

3.4 What Is the Impact that Digital Health Technology May Bring from the Perspective of One Health?

The notion of One Health puts a stronger emphasis on how to evaluate the impact of digital health technology on people, communities, and nature from a regional, national and global perspective. It is important to measure the intended and unintended consequences that information systems have on the well-being of people, animals, plants, and the environment. Well-designed health information systems may contribute to several indicators that are relevant to the one-health perspective:

- Telemedicine and virtual clinics could reduce travel (and thereby environmental impact) and treatment burden and improve the quality of care for populations in remote settings [24, 25];
- Robust IT infrastructure and IT-based collaborative tools could support virtual networks of people and institutions and thus support the idea of empowerment, solidarity, sharing, and trust, and encouraging active citizen engagement [20];
- The way IT-based services are developed and maintained has a large impact on CO_2 emissions and sustainability of the health and care sectors [25];
- Access of people to their own health-related data, to personalized recommendations and to general health-related knowledge can foster equity and environmental justice;
- Provide access to unbiased sources of information to contract consequences of social media misinformation and disinformation;
- Adoption of pollution-related disease classification codes and information systems that harvest pollution data can impact wellbeing of populations [26];
- Epidemiological monitoring systems on a global level can help to detect and address the spread of zoonotic diseases, pandemic challenges, and antimicrobial resistance and improve national security [15, 27, 28], including surveillance of animal health [29];
- Informatics may provide solutions for effective storage and retrieval of pathogen data in biobanks [28].
- Development and adoption of new interoperability standards, ontologies, and data analysis models including AI models could improve interoperability, data sharing, and diagnostics [30];
- Clinical decision support systems (CDSS) can advise providers and patients to reduce ordering/use of tests, medications, procedures [25]; for example, such systems could recommend more appropriate antibiotic regimens (or the avoidance of antimicrobials) and reduce the spread of antibiotic resistance [31].

3.5 How Can the One Health Approach be Incorporated into the Existing Evaluation Paradigm?

The One Health perspective demands that new health IT has also to consider the regional, national and global impact on the health and wellbeing of people and communities. This is typically not a routine focus for a health IT evaluation study. Health IT evaluation research thus needs to work on the following challenges:

- Develop a list of indicators that reflect the impact of health IT from a One Health perspective.
- Develop methodologies and tools to make these indicators measurable.
- Assess these indicators at each health IT lifecycle phase, including assessment of supplier green credentials, corporate values, and ethics at the planning phase.
- Revise guidelines (such as GEP-HI [32], ELICIT [33], TPOM [34]) to include these aspects in future evaluation studies. Add new ethical and environmental dimensions to the existing evaluation frameworks.
- Broaden the education and certification of informaticists, physicians, and veterinarians to include multidisciplinary, environment-oriented perspectives on the evaluation of IT systems.
- Improve communication and coordination between different government agencies and organizations to reduce the information silos and promote data sharing [35].

In summary, global health threats such as climate change, antimicrobial resistance, and COVID-19 pandemic demonstrate the importance of breaking down some of the educational, methodological, theoretical, and policy barriers to using One Health approach in the evaluation of Health IT.

We believe that methodological and theoretical evaluation approaches need to be updated to allow evaluation of One Health outcomes such as sustainability, health equity, and trust among communities. Special attention should be paid to the unprecedented level of collaboration required from diverse stakeholders that have previously not realised this need. This emphasises the value of inter-disciplinary and trans-disciplinary generalists that can work across and between professional siloes to mediate positive change [36, 37].

4 Why Does Human Factors Science Need to Consider the One Health Worldview?

The International Ergonomics Association (IEA) defines ergonomics (or human factors ergonomics, HFE) as "*the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance*" [38]. The HFE discipline has long been aware of environmental issues including water scarcity, excessive energy use, pollution, and waste [39]. The IEA even established a technical committee "human factors and sustainable development" in 2008. Yet, the development of theoretical models and research on the role of HFE in the mitigation and management of environmental issues like global warming only truly started in the 2010s with the start of the concept of green ergonomics (HFE interventions that have a pro-nature focus) [40, 41].

Until recently, sustainability or environmental concerns were not at the centre of healthcare HFE research. HFE in healthcare primarily focuses on enhancing patient care and safety as well as ensuring the well-being of healthcare professionals, non-professional caregivers and patients as depicted by the outcomes of work system models like SEIPS 2.0 [42]. Yet, healthcare activities including information technologies contribute to greenhouse gas emissions and global warming [43, 44].

Therefore, HFE applied to health informatics, especially usability, the "*extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use*" [45], should add a sustainable ecological footprint to their research objectives of care and safety of patients, and well-being of stakeholders in the care process. Software with poor usability typically requires a longer user-interaction duration and, therefore, increases the energy consumption. Software that is easy to use is less likely to be laboriously utilized, leading to better user-interaction and lower environmental impact. Few studies have tested this hypothesis but results are accumulating that show that several usability characteristics of graphical user interface are positively linked to a lower energy consumption [46, 47]. Even if further research is required, those findings demonstrate that HFE must keep working on enhancing the usability of digital healthcare technologies at an individual level. From a broader perspective, a green user experience (UX) design approach to healthcare software might be a solution to improve the usability of the technology and their users' experience and to decrease the carbon footprint of those technologies. The main principle of the green design is "less is better" [48]: propose only features the users actually need, display less information but better organized, use less different fonts, less data entry etc. Adopting this approach will make the interaction between the user and the technology easier and more efficient. Therefore, users will need less time to complete their tasks with the technology which will increase their satisfaction and efficiency but also their energy consumption-related carbon footprint. More research is still needed to determine how green UX design affects user experience and ecological outcomes.

Digital health technology may also promote more environmentally friendly uses of medications in addition to reducing the environmental impact of their production and consumption. Pharmaceutical products-related carbon emissions are more intensive than those from the automobile sector [49] and could be a starting point to reducing healthcare sector greenhouse gas emissions [50]. By improving drug adherence [51], mHealth apps could help reduce the pollution caused by wasted medications. CDSS integrated into prescribing software are used to optimize medication use. Studies have shown that they contribute to reducing the risk of iatrogenic disorders [52] and that they can also modify physicians' prescribing behaviour, such as reducing antibiotic overuse. By making prescribers aware of the cost of the medications they selected and by promoting the use of generic medications, these CDSS have made it possible to significantly reduce medication expenditure [53–55]. The same mechanism could be applied in veterinary antibiotic prescribing or to raise awareness of the carbon footprint of prescribed medications: CDSS could for instance propose treatments with a lower carbon footprint with equivalent effect and efficacy. To our knowledge, no study has yet been conducted on this topic.

Research in the field of HFE is needed to develop and evaluate digital health technology that could motivate green medication behaviours and improve usability. However, technologies are only one component of work systems, as are people (the actor in the process), tasks (the activities to be performed), the internal environment (light, sound, physical layout), the external environment (regulations, protocols), and the organization (the way work is organized) [42]. If technology does not fit well with other components of work systems (*e.g.*, discrepancy between the work model implemented in the technology and actual work processes, unmet user needs), it can disrupt the work process, add workload to users, fail to produce the expected positive ecological outcomes, and ultimately be rejected by users and contribute to technology waste. Therefore, HFE research must deepen their understanding of the work system from a meso-ergonomic perspective, considering several levels together [56]: individual (technology, skills, tasks), organizational (information system, protocols, human resources and training), national (health and medication policy, regulation) and international (medication and technology production and market) levels. Furthermore, to drive more ecologically virtuous change, the focus of HFE research should not be solely on a given work system; it is necessary to take into account all upstream and downstream systems. For instance, analyzing the systems that create and transmit energy, as well as the systems that patients use at home to manage and use the medications prescribed to them while they are in the hospital, is necessary to reduce the impact of a hospital's medical informatics technology. Otherwise, the desired changes may not be feasible.

In summary, HFE research and initiatives are crucial for truly eco-friendly digital health technology. However, consideration of ecological objectives in the same way as the objectives of patient care and safety and the well-being of the actors in the healthcare system requires a broader and deeper look at systems of healthcare work.

5 Conclusions

Health in its broadest sense, according to the WHO definition, is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [57]. One Health makes us realise that this cannot be achieved solely by human healthcare or healthy living. Health is a planetary issue that requires collaborative action. The interdisciplinary theories and principles of BMHI [58] and the digital health technology that operationalises data, information and knowledge are not neutral actors in the One Health space.

The three IMIA working groups represented in this article are actively collaborating to highlight ODH, through integrated work leading to panels, workshops and joint papers at the conferences of IMIA and its regional bodies European Federation for Medical Informatics (EFMI), American Medical Informatics Association (AMIA), and Asia Pacific Association for Medical Informatics (APAMI), and opportunities for student and intern supervision, such as through the International Partnership in Health Informatics Education (IPHIE) [59].

Our consideration of this topic using three distinct lenses offers diverse but complementary perspectives and suggests emerging consensus about the crucial importance of:

- Broadening our understanding of 'context of use' to incorporate animal health and the environment;
- Going beyond systems thinking to socio technical 'ecosystems thinking';
- Further developing interdisciplinary collaboration at multiple scales;
- Revising evaluation frameworks to take a One Health approach;
- Identifying synergies in service transformation, such as virtual clinics not only being good for the environment but reducing patient treatment burden;
- Re-considering the idea of population health to incorporate non-human populations, diseases, risks and ecological consequences;
- Pursuing specific opportunities, such as veterinary decision support to improve antimicrobial stewardship in farming and companion animals;
- Avoiding 'greenwashing' by visualising technology 'clouds' as harmless and far away, but striving to reduce the planetary cost of planned obsolescence and technology over-use.

One Health thinking offers us powerful insights. The challenge is to recognise the actions required and to collaborate to achieve them.

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