Transforming knowledge systems for life on Earth: Visions of future systems and how to get there

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ABSTRACT

Formalised knowledge systems, including universities and research institutes, are important for contemporary societies. They are, however, also arguably failing humanity when their impact is measured against the level of progress being made in stimulating the societal changes needed to address challenges like climate change. In this research we used a novel futures-oriented and participatory approach that asked what future envisioned knowledge systems might need to look like and how we might get there. Findings suggest that envisioned future systems will need to be much more collaborative, open, diverse, egalitarian, and able to work with values and systemic issues. They will also need to go beyond producing knowledge about our world to generating wisdom about how to act within it. To get to envisioned systems we will need to rapidly scale methodological innovations, connect innovators, and creatively accelerate learning about working with intractable challenges. We will also need to create new funding schemes, a global knowledge commons, and challenge deeply held assumptions. To genuinely be a creative force in supporting longevity of human and non-human life on our planet, the shift in knowledge systems will probably need to be at the scale of the enlightenment and speed of the scientific and technological revolution accompanying the second World War. This will require bold and strategic action from governments, scientists, civic society and sustained transformational intent.

1. Introduction

The world has entered a new era of rapid and major change. Significant shifts are occurring in global economic power, technology, urban growth and through environmental changes that pose existential threats to humanity, such as climate change and the destabilization of the ecosystems on which human life depends [1,2]. Given current trajectories, transformation of human societies in some form is inevitable. It is, however, not clear whether global transformations can be navigated to avoid catastrophic environmental change and ensure more desirable trajectories of human and non-human life on our planet [3,4]. Such navigation requires active stewarding of systemic societal and technological change across diverse sectors of society and challenging deeply held assumptions underpinning unequal and environmentally degenerative patterns [4,5]. Financing transformations, for example, requires transformations in financial systems [6] while narratives to support transformations require transformations in the way narratives are conceptualized, produced and applied [7].

Knowledge, and the systems supporting its production, are no exception. Knowledge systems include the practices, routines, structures,

mindsets, values and cultures affecting what and how knowledge is produced and used, and by whom. Such systems include elements (institutions, structures, assumptions, values, standards); functions (generation, validation, communication and application of knowledge); and contexts (organizational, operational, political) [8]. Formalised knowledge systems can be taken to include the elements, functions, and contexts associated with universities, research institutes, non-government and government organizations. These systems produce knowledge and technology developed through the sciences, social sciences, humanities, the arts, industry and commerce. Formalised knowledge systems (herein knowledge systems) are closely intertwined with society, economies and cultures and are integral to shaping the way societies develop, function and mobilise resources [9]. While they are extremely important [10–13], they may also reinforce current patterns of thinking and action, limiting ability of societies to develop capacities for more creative responses to challenges like climate change and energy transitions [14,15].

There have been many critiques of the relationship of knowledge systems to society and how they reinforce power structures, political ideals and economies [14,16–23]. There are also many examples of innovative approaches that seek to find new ways of working with knowledge creation from which many lessons can be learned [24–27]. As yet, however, there has been limited analysis of how system level

transformations might be encouraged towards new knowledge systems that are more viable in a rapidly changing world. This paper begins to address this gap by exploring how transformations in knowledge systems might be stewarded. This includes examining the challenges inhibiting the ability of current knowledge systems to help navigate global transformations, exploring what a more viable future transformed knowledge system might look like and some of the domains of action needed to help facilitate systemic change. The findings are based on an extensive and innovative participatory, futures and systems-oriented approach which elicited knowledge of 340 delegates of the Transformations to Sustainability conference in Scotland in 2017. The paper first explains the need for knowledge system change, followed by the methods, results and discussion. Overall, the paper makes a novel contribution by going beyond critiquing existing systems and identifying what is needed to also examining how change in knowledge systems could be facilitated.

1.1. Knowledge systems and societal transformations

Over the last 300 years knowledge systems have generated many benefits and have transformed the human condition [28]. Despite this, scholars from diverse fields have questioned the ability of current knowledge systems to work effectively with current societal challenges [14,15,20,29]. This includes fields such as energy, buildings, transportation, sustainability, the life sciences and geography which have called for greater involvement of the social sciences [30–32], greater rigor (depth), interdisciplinary reach (breadth), and policy-relevance [33–37]. In climate and energy research the field has been criticized for being marked by 'disciplinary chauvinism' [38], with authorship tending to be male and western [38,39] implying hierarchical and exclusionary tendencies that reflect broader societal and transnational socio-economic and political inequalities. Energy research scholars have also called for substantial change of knowledge production patterns to improve their societal contribution and relevance [36,38,40–42] such as through greater integration of disciplines [43] and co-creation of knowledge by diverse actors [44–46]. Such work highlights the need to strengthen critical-reflexive and qualitative studies [47–49] and increase both pragmatic studies of what can be done and ethical considerations of what should be done [50,51]. This requires greater attention to asking how research affects the researched [52,53] and embracing non-traditional researcher roles [54].

While such critiques are important they tend towards recommending changes in research methodology rather than towards more fundamental critiques about knowledge systems as a whole. Importantly, critiques tend to overlook the problem that while current knowledge systems have led to major advances, they have also generated phenomenal capacity for humanity to create harm, such as by enabling war and annihilation of biodiversity, cultures, and languages [55]. Many contemporary challenges have themselves emerged from scientific and technological advances that current knowledge systems have produced, such as climate change, loss of biodiversity, obesity, smoking, premature deaths from air pollution [15] and the ethical dilemmas posed by artificial intelligence and automation [56]. Our current knowledge systems are thus arguably failing humanity when their impact is measured against the level of progress being made towards the deep and rapid societal changes needed to avoid existential threats from global environmental change [57]. Fundamental shifts will thus be needed if knowledge systems are to transcend the thinking and

approaches that have led to many contemporary challenges like climate change and ensure knowledge systems can more effectively support wider societal transformations.

There are some helpful shifts in knowledge systems that are already occurring. Comprehensive studies have highlighted emerging paradigmatic shifts in science-society relations [16,20,28,58], albeit through largely descriptive research of past and current trends rather than explicitly on how transformation of those systems might be achieved. There have also been many important developments in new scientific disciplines and fields of research, such as sustainability science [10], integration and implementation science [59], transformative science [60], resilience [61] and sustainability transitions research [62]. New collaborative practices, for example, are gaining wider acceptance and prominence such as transdisciplinary, participatory-action, citizen science, co-creative and transformational research [24–26,63–65] and new arenas for knowledge creation are emerging [66]. A growth in methodological pluralism is leading to new core research questions, strategies, innovations and understanding of the kinds of infrastructures needed for wider change in knowledge systems to occur [28,67–69].

Considerable insights also already exist about the kinds of new systems we may need, such as for those that attend more directly to how science is shaped by society [14], for new underlying assumptions [28], and the need to integrate the production of knowledge also with considerations of what is 'good', 'right' and 'beautiful' [15]. There is also a need for new kinds of knowledge systems that are much more open and democratic with some broad suggestions of how this might be achieved [67]. Yet, while such work is promising and shifts are beginning to occur, we are still a long way from enacting the ideas involved. Thus, while knowledge systems have always been evolving, there is now a need to go beyond the 'what' to examining 'how' new knowledge systems might be encouraged.

2. Materials and methods

2.1. Approach

This research asks how changes in knowledge systems could be facilitated to support societal transformations. To achieve this, and in accordance with guidelines for rigor in qualitative social science [36], we outline our broad approach, our epistemology (our position on what counts as knowledge and knowing) and specific methods used. Our work was broadly framed as second order science, which rejects the commonly held assumption in science and research that an observer can or should be independent to what is observed [28,57]. Observer-independence is largely a fallacy, as all research is in some way influenced by society. For instance, through researchers being influenced by the cultures, norms, mindsets, motivations, systems and structures that affect what is funded or which questions receive attention [28,70]. A second order science approach shifts focus away from studying a system as if looking in from the outside to conducting research as if from within. This includes reflexively examining one's own role in the way a system is reproduced. This opens space for inclusion of more diverse forms of knowledge and knowing, such as practical, experiential and embodied forms of knowledge [57]. The approach taken corresponds to recent calls for more relational, reflexive and co-creational methodologies, in energy and climate change research [44,45,53] and sustainability science more broadly [24,57,64] and wider shifts that are occurring towards more societally relevant research [28].

The second order approach was delivered using a co-creative, participatory, futures and transformation oriented methodology called Three Horizon's practice [71] which focused on understanding: (1) the challenges of current knowledge systems; (2) what future, more effective systems might look like; and (3) the domains of policy and practice needed to help facilitate shifts from the current to the future desired knowledge systems. Three Horizons uses a simple framework to structure dialogue about how such pattern shifts might be facilitated [71] (Fig. 1). In this framework, the future is imagined as emerging through three overlapping horizons with each representing the prevalence of particular ways of doing things (e.g. practices, approaches, technologies, values etc.). These aspects wax and wane over time as their viability changes in the face of a wider changing context (e.g. technology, climate or economic change). Some ways of doing things in the first horizon naturally decline because they are no longer relevant while new third horizon activities emerge and eventually become the new pattern in the future. Disruptive second horizon innovations are then key for creating space for third horizon patterns to emerge (Fig. 1).

The Three Horizons approach is considered a practice because it is a facilitated process that helps convene conversations, such as about how

actions in the second horizon space can help stimulate emergence of new patterns. It results in a 'map' of differences between current and desired future systems and ideas about the innovations that would help such a pattern shift occur. The approach is suited to working with uncertainty and enhancing agency to support transformative pattern shifts, such as towards new kinds of knowledge systems that can be more viable in a world of rapid change [71].

2.2. Epistemology

Three Horizons practice involves working with three different kinds of knowledge. First, expertise of current systems was elicited to answer the first question about challenges inhibiting the ability of current knowledge systems to support societal transformations. Expertise is an embodied form of knowledge, which is usually implicit or tacit, and difficult to make explicit and is particularly relevant for exploring and identifying patterns within systems [72]. In this part of the methodology the process was akin to an evidence-based approach with the 'evidence' being in the form of 'expertise' based on real experiences from the past about existing knowledge systems.
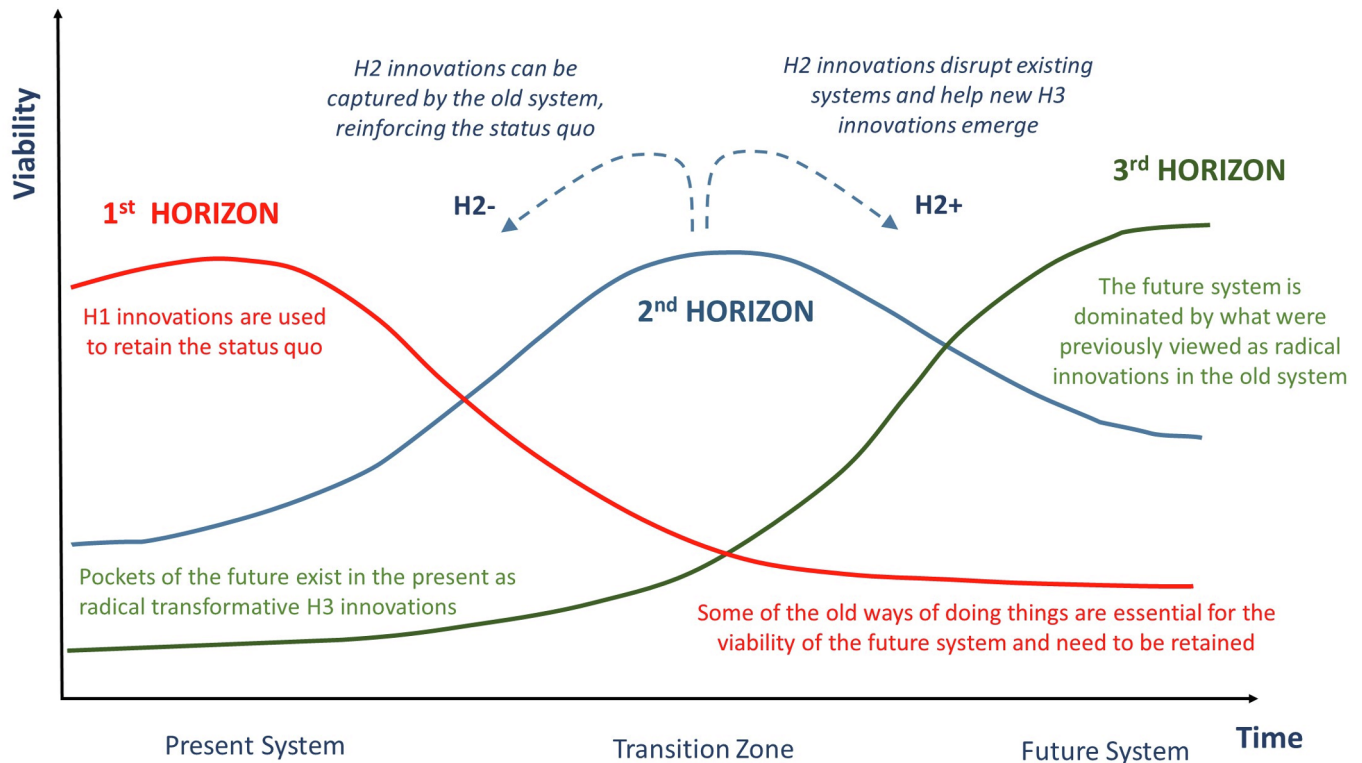

Fig. 1. The Three Horizons framework used to convene dialogue about how to achieve transformation. Each horizon represents a combination of particular ways of doing things (e.g. approach, technology, actions, values, mindsets). The viability of these ways change over time as surrounding conditions change, with the third horizon dominated system eventually emerging as more viable. The framework helps to identify: (1) Challenges that dominate the present that inhibit progress towards a more viable way of doing things (Horizon 1); (2) Features of a desired future systems (Horizon 3) and the innovations needed for new systems to emerge (Horizon 2). For the latter, distinctions are made between innovations that help create forward momentum (H2 +) and those likely to be captured by existing systems and which can reinforce the status quo (H2 −). This framework is not a theory, but rather seeks to support the practice of identifying pathways for system change.

Relying on knowledge from the past to envision a new transformed future is not sufficient because it can constrain imaginations of what might be possible, analogous to driving forwards while looking through a rearview mirror [73]. Thus, to address the second question and identify envisioned future third horizon knowledge systems, anticipatory and imagined forms of knowledge were elicited. The goal here was to draw out intentionally visionary and normative aspirations of participants. Engagement with such normative dimensions is critical for shaping change [57,74] and providing inspiration, aspiration, and values based notions about what transformations might look like [15,74]. Rather than trying to represent a universal truth of *what will be* our goal was to elicit personalized truths about what participants *desired the future to be* in a wider context of a rapidly changing world and existential threats like climate change. Such futures oriented normative knowledge is still a truth in the sense that it is 'true' to those who express it but is not a truth in the way evidence is usually conceived.

Finally, contrasts between current and future systems help orientate the development of actions best suited to facilitating a pattern shift [75]. It relies on contrasts between understandings of the current system versus visions of future desired systems which then enable identification of appropriate action in the intervening space to occur. Knowledge was thus also elicited about what needed to be implemented in the second horizon for the third horizon to emerge. This knowledge was a form of creative knowledge bridging experiential understandings of current systems and normative anticipatory knowledge of what was desired. Importantly, this required co-creating possible domains of action and avoiding actions that could be co-opted and used to prop up and improve existing systems. Overall, Three Horizons practice helped work with and combine collective expertise, anticipatory, and creative forms of knowledge to determine how possible re-patterning and transformations in knowledge systems could be encouraged and supported.

In addition to eliciting knowledge and perspectives, the research also encouraged conference delegates to help validate integrated findings and shape the overall narrative of the paper through multiple phases (see below). As such delegates were considered to be participant-researchers – more than just participants from which knowledge was extracted – and invited to be co-authors. While this might be argued as reducing rigor, this would be a misunderstanding of the second-order science approach being applied. In this case, validity of the work was considered to have been enhanced precisely because the participant-researchers had direct knowledge about the systems they were embedded in and the way they were included in the process of developing the paper as a whole. Thus, while the paper has limitations, its methodology is intended to be a challenge to existing assumptions and provide an example of an alternative way of approaching research as is likely needed in a new, more egalitarian knowledge system as highlighted in the results of this paper.

2.3. Data collection and analysis

Three Horizons Practice provided the focus for eliciting the different kinds of knowledge from the 340 participants, who had diverse backgrounds relating to social and environmental change and sustainability. Approximately 70% of these had primarily academic backgrounds and 30% practice and policy professional backgrounds. Many participants actively worked across academic and practice domains and combined conceptual thinking and research with practice. Collectively, the expertise of participants spanned action-oriented and co-production research methodologies as well as more traditional scientific, social science and arts-based approaches and disciplines. This enabled coverage of empirical, pragmatic and ethical perspectives and, to a degree, the integration of social and natural science perspectives and experience, which are important for enhancing methodologies in energy and climate related research [43,54].

The deliberative process included ten parallel, three-hour workshops (Box 1). Each parallel workshop was professionally facilitated and included 4–6 focus groups of 4–6 individuals. Together this equated to: 45–50 discussion groups, 135–150 h of group discussions; and around 750 h of participant involvement. In each workshop groups consecutively discussed each of the three questions, identifying 4–6 points per question. After each group in a workshop discussing a question for 20-30 min, each group put forward 1–2 of the most important points, adding them to a three-horizon map on the wall. This resulted in a total of 754 ideas with 211 items identified as the most important. This included 61 challenges; 66 relating to future envisioned systems; and 84 to actions to help the future envisioned system emerge.

Eleven analysts worked overnight at the conference and during the morning of the final day of the conference to integrate the 211 items from the ten different three Horizon maps. A generative approach, which focuses on creation of new representations [76] was used that involved coding items associated with each horizon to identify overarching themes. This included using Hexagon mapping (https://resources.h3uni.org/) to help ensure the process took into consideration relations between items rather than just providing simple categories. The preliminary findings were then presented back to conference delegates on the final day.

Preliminary results were refined by eight analysts through three stages that used robust qualitative methods to produce separate narratives for the results relating to each of the three horizons. The last iteration also involved identifying key emergent properties of the current and future envisioned systems (i.e. those aspects that were not a property of any single component of a system) to help make explicit the contrasting qualities of current and desired future systems. Finally, the three narratives were combined to create a coherent single narrative (a draft research paper).

The draft paper was shared with all participants for their comments using a survey that collected answers to quantitative and qualitative questions about degrees of agreement relating to the work presented and suggestions for its improvement. 184 individuals opened and initialized the survey, with 156 completing it and agreeing to become co-authors. Following further contact with incomplete responders, four rejoined. Of those who responded to the survey, 86% were 'extremely supportive' of the results and narrative, and expressed a feeling the paper was either 'ready' or 'close to being ready' for submission. 14% were 'somewhat' supportive and/or felt that the narrative needed changing. The 500 comments from the survey mostly focused on details and overall narrative rather than questioning the results. Comments were sorted into key themes to be addressed and where possible specific comments were also dealt with. It is not fully known as to why other participants either did not respond or declined to be authors. Informal feedback from some did suggest, however, that it was because they felt they had not contributed sufficiently rather than because they had significant disagreements with what was presented.

Research Aim

How do knowledge system need to transform to support societal transformations towards regenerative futures?

Framing

Second Order Science where researchers are assumed to be part of the systems they study

Approach

Eliciting expertise, visions, and creative knowledge using Three Horizons Futures practice

Questions

Q1 What are the challenges inhibiting the ability of current systems to support transformations?

Q2 What would be incorporated in a new envisioned system?

Q3 What innovations are needed to enable the new future system to emerge?

Participants

- 340 delegates from Transformations 2017 conference;
- Diverse social and environmental backgrounds with focus on social and environmental sustainability;
- Approximately 70% primarily academic and 30% practice and policy backgrounds;
- Many participants actively worked across academic and practice domains;
- Expertise spanned action-oriented and co-production research methods and scientific, social science and arts-based approaches;
- The majority from the global north with poor representation from countries with developing economies.

Data Collection

- 10 parallel workshops, 4-6 discussion groups per workshop, with each group having 4-6 people, working for 3 hours;
- Discussion groups answer each question, items added to the Three Horizons Map
- Dialogue across a workshop builds consensus while items enable diverse perspectives to be included;
- Data includes: 45-50 discussion groups; 135-150 hours of group discussion; around 750 hours of participant involvement; 754 ideas generated; 211 identified as most important (Q1 = 61, Q2= 66; Q3 = 84).

Analysis

- 11 core analysts collated the 211 items and used generative methods to develop core themes;
- Preliminary findings reported back to conference delegates;
- 8 core analysts clarified themes and co-developed narratives in three iterative stages;
- Overall narrative and analysis was checked and validated by participants using an online survey;
- Revision of overall narrative and analysis by core analysts based on feedback by participants;
- Redistribution of overall narrative to participants for them to confirm their inclusion as an author.

Box 1. The research methodology.

Multiple checks and balances were used throughout the process to ensure the results and narrative reflected the views and perspectives of researcher-participants and reduce biases created by interactions of research-participants acting in different roles, such as facilitators, analyst and participants in accordance with suggestions for enhancing rigor [36]. This included: (1) Sharing and deliberation of ideas in the parallel workshops at the conference; (2) careful coding and preliminary analysis using multiple analysts who had been present in different workshops; (3) feeding back preliminary analysis to participants during the conference; (4) multiple iterations of cross-checking by multiple analysts post conference; (5) working with comments from the researcher-participants about the overall narrative; and (6) final approval of the narrative through participants by agreeing to be a co-author before the paper was submitted. In this last stage, only one person declined to be an author, while four newly joined after email communication errors had been clarified. Combined with the facilitators and analysts, this led to the total of 183 authors on the paper. In conclusion, while a different group of participants may have led to

different findings, our extensive attention to validation means the findings can be considered to be a robust representation of the knowledge of the diverse participants who were involved.

3. Results

3.1. Challenges of existing knowledge systems

While current knowledge systems are important, diverse and significant challenges were identified that inhibit their ability to help navigate global transformations (Fig. 2, Table 1). Challenges identified included: tendencies for knowledge and knowing to be viewed in narrow ways, reducing opportunities for new kinds of thinking and learning; fragmented and compartmentalised knowledge production organised around powerful highly self-referential and disconnected disciplines which do not sufficiently take account of the highly interconnected nature of social and environmental issues; and tendencies to produce knowledge separately from practice, limiting opportunities for
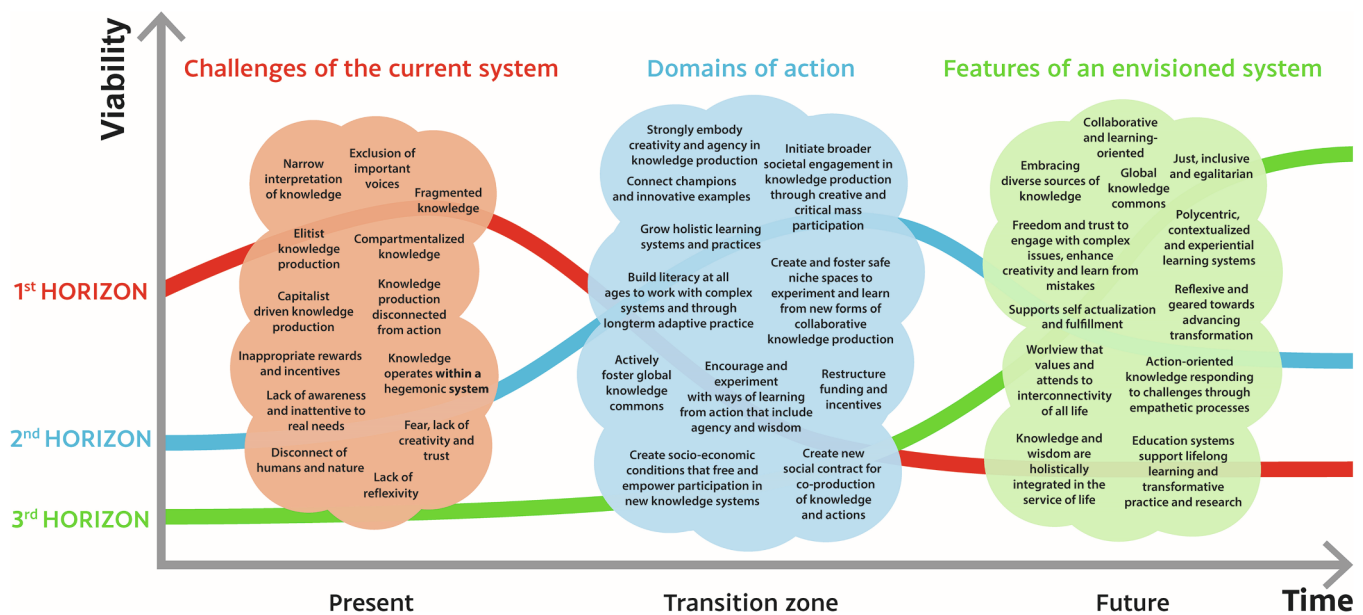
Fig. 2. Pattern shifts from current challenges to future envisioned systems more able to support emergence of regenerative and equitable futures, with key domains of policy and action that are needed to help this shift emerge.

more innovative solutions (Fig. 2, Table 1).

Importantly, knowledge that tends to get accepted in current knowledge systems was suggested to be that which supports existing ways of doing things, reinforcing existing social, economic and political forms of power and thus limiting emergence of more creative ways of working with global challenges (Fig. 2, Table 1). The knowledge produced in formalised systems was also often highlighted as being elitist, exclusive, disconnected from the public, and with limited relevance to the scale of the challenges facing the planet. These issues were viewed as being reinforced by wider society where there is a general lack of demand for change and where human interests dominate over nature (Fig. 2, Table 1). Further, formalised knowledge production was considered to be dominated by western systems which pay cursory attention to, for example, indigenous knowledge. This western dominant system tends to be driven by a growth-based economy with knowledge viewed as a commodity, emphasising speed over quality, profit over wellbeing, achievement over fulfilment, and competition over collaboration. In this context, doing things differently can be very challenging. For example, many participants who worked in existing knowledge systems expressed fear of deviating from current norms, incentives and paradigms and felt that opportunities for creativity and questioning underlying assumptions and motives driving research were limited. The result has been knowledge systems primarily supporting incremental rather than the systemic kinds of change needed to work with 21st century challenges.

The many significant benefits of current knowledge systems were, however, also acknowledged. Past and current forms of knowledge production have developed phenomenal capacities to understand biophysical and human social phenomena. They also include sophisticated systems of universities, learned societies and funding infrastructures with enormous capability and potential. This has led to major advances in learning about global social and environmental challenges and provided the foundations for re-shaping how humans think about their place in, and influence on, the world. Current systems also include a highly developed community well placed to maintain a high level of concern about the status of the planet and a basis from which fake news and misinformation can be challenged. This has all been made possible by methodological advances in data collection, management, analysis and representation.

Yet, while current knowledge systems are extremely effective at producing knowledge with ever larger datasets to speed up computers, produce research papers and advance learning about the world, they have yet to develop a means of coherently linking and solving the problems the same systems have also helped to produce. Current systems still have limited capacity to support genuinely integrated, inclusive knowledge and generative and creative modes of knowledge production relevant to the new era in which researchers and society find themselves.

3.2. Envisioned future knowledge systems

Given the limits of current knowledge systems, a critical question then emerges about the kinds of future knowledge systems that could be more effective in supporting societal transformations. Such systems were envisioned as needing to be much more: collaborative; inclusive of different forms of knowledge; and capable of working with complexity, values, and diverse human and non-human interests (Fig. 2, Table 2). They would be focused towards cultivating 'know-how' practical knowledge about how to work with 21st century challenges to complement the 'know what' knowledge about their nature that currently dominates research. They were also envisioned as having a much stronger focus on learning about how to achieve transformative and systemic outcomes, as well as supporting much more diverse, pluralistic, egalitarian and creative modes of knowledge production. These modes would be capable of working with ethics and aesthetics in combination with knowledge and encourage research to be accountable to society (Fig. 2, Table 2) and would include a much wider diversity of people recognized as legitimate producers of knowledge.

In future systems knowledge producers were envisioned to be actively supported to work on complex, open-ended and less compartmentalized issues where mistakes and conflicts are viewed as important sources of learning (Fig. 2, Table 2). This would promote greater understanding of how subjects of enquiry related to their larger wholes and reduce piecemeal and silo-based thinking and action. To support such work, more pluralistic, distributed and self-organizing structures would incentivize development and application of context specific insights as well as produce more generalizable knowledge. Examples of such supportive systems would be an education that encouraged holistic and integrative thinking and knowledge sharing cultures that

Table 1
Challenges inhibiting knowledge systems to support the navigation of transformations.

Challenge	Explanation	Emergent property
Narrow interpretation of knowledge	Creativity, innovation, and transformation is not sufficiently supported because of a narrow understanding and interpretation of what counts as knowledge and knowing and where positivist epistemologies are dominant. This understanding of knowledge is disconnected from values, emotions, and contexts and the quality criteria applied do not encourage innovative and action-oriented approaches. The dominant epistemology is reinforced by particular models of development and a material relationship of humans with nature. Knowledge must be understood as subjective, complex, multi-dimensional and as a vehicle for change.	Knowledge focused, Narrowly informed, Avoids ethics & aesthetics
Fragmented knowledge	Knowledge production and use often lacks systemic thinking and is dominated by linear and fragmented understandings of reality. Much of the emphasis is also on intellectual (e.g. theory generation) rather than solution-oriented perspectives and there are challenges in balancing intellectual knowledge with other forms, such as emotional, tacit and relational knowledge.	Fragmented & Disconnected, Science for science, Observant and abstracted
Compartmentalized knowledge	Knowledge production is often organized in disconnected disciplines, and conforms to explicit and implicit norms of academic and practitioner cultures. Knowledge is produced by experts in dominant ways of knowing, rather than through more comprehensive or complex understandings. The compartmentalized structure leads to strong path dependencies that constrain emergence of new ways of knowing and acting. The focus is on producing globalised knowledge rather than knowledge relevant to local issues and contexts.	Fragmented & Disconnected, Self-referential & uncritical, Outcomes for a few, Globalised knowledge, Narrowly informed
Elitist knowledge production	Much of current academic systems, structures and practices are highly specialized, exclusive, dogmatic, have limited attention to effective communication, and are self-referential. This privileges certain kinds of institutions as owning or producing knowledge, slows emergence of new thinking, and furthers disconnections between science and research and real world issues.	Elitist, exploitative & exclusive, Science for science, Outcomes for a few
Exclusion of important voices	Knowledge production tends to exclude marginalized perspectives, because of power, gender, economic, and social inequalities and the biases in research. Most producers are from elite elements of society excluding the poor, the young, the old, women and different cultures and ethnicities. This can include exploitation of potential research users, such as by limiting involvement of diverse stakeholders in question identification, data analysis or interpretation.	Elitist, exploitative & exclusive, Outcomes for a few
Knowledge production disconnected from action	Knowledge production is often considered separate from the realm of action, limiting learning about change. Academia specializes in identifying and analysing problems and less on implementing solutions. Know how knowledge, held by practitioners, tends to be viewed as having limited value in academic domains. Value systems behind knowledge production for action tend to focus on retaining the status quo, rather than on transformational change.	Fragmented & Disconnected, Incremental
Rewards and incentives favouring current systems	Formal knowledge production (e.g. by academics) is regulated by incentives and reward systems that limit production of certain kinds of knowledge. For example, research assessment frameworks tend to favour disciplinary splits and undervalue practical forms of knowledge that may be more relevant to real-world problems or transformative change.	Self-referential & uncritical, Science for science
Fear, lack of creativity and trust	Reward and incentive structures favour competition, silos, individual and egocentric forms of working. Knowledge workers deviating from these norms risk livelihood harm or marginalisation, contributing to fear, lack of creativity and trust.	Competitive, Fear, Low creativity
Uncritical production systems	Current systems lack critical questioning of underlying assumptions, blindspots and how the systems are influenced by and are part of, broader societal worldviews and structures. The focus is on providing knowledge from the sidelines for others to act upon rather than reflecting back on the way current knowledge systems reinforce themselves or constrain societal change.	Self-referential & uncritical
Knowledge operates within hegemonic systems	Current knowledge production systems take place within wider societal intellectual, economic, and power systems where knowledge that gets accepted and used tends to be that conforming to or supporting existing structures and power dynamics. What research gets funded and accepted is heavily influenced by such structures and norms. This can silence alternative voices or marginalize particular issues. It can prevent effective use of what is already known.	Incremental, Outcomes for a few
Lack of awareness and attention to real needs	Societies in which knowledge systems are embedded are not sufficiently aware ofExperiment, Build new the state of the planet and demand for knowledge for change is lacking. There are multiple barriers to accessing knowledge about planetary conditions and change, which combine with elitist knowledge production to limit attention to challenges in society, science and research.	Fragmented & Disconnected
Disconnect of humans and nature	Knowledge production often occurs by separating the self (e.g. a researcher) from the natural and social world. This view, originating largely in dominant modes of Western thought, tends to disregard or subordinate nature to human interests. It assumes the ecosphere and natural resources are manageable and that human actions can occur without ecological impact.	Fragmented & Disconnected, Narrowly informed
Capitalist-driven knowledge production	Knowledge is driven by and oriented towards values of a capitalistic society, prioritizing speed over quality, profit over usefulness, achievement over fulfilment, and competition over collaboration. This leads to narrow views of what counts as 'useful' research and the support of unsustainable economies. Much of research itself is not environmentally sustainable.	Competition, Narrowly informed

Table 2
Characteristics and emergent properties of envisioned knowledge systems.

Characteristic	Explanation	Emergent properties
Collaborative and learning-oriented	Knowledge systems are open to diverse stakeholders, are founded on collaboration and a desire to stimulate learning. This enables co-design, co-production, and co-delivery of knowledge to create outcomes which serve society as a whole. It involves democratic participation, supportive institutional structures, and humility of those involved.	Collaborative
Embraces diverse sources of knowledge	Many types of knowledge are utilised and valued, including those that go beyond conventional rationalistic forms. There is an openness to different ways of knowing, such as intuitive, experiential, and traditional indigenous forms of knowledge.	Widely informed
Just, inclusive and egalitarian	Knowledge systems are fair to all involved and are non-exploitative, including the stakeholders who produce and use knowledge. For example, relevant stakeholders have opportunities to participate, have views heard, ideas and concerns appropriately incorporated, and non-human interests are considered.	Egalitarian, equitable and inclusive, Outcomes for everybody
Action-oriented knowledge responding to challenges with empathy	Knowledge and action is complementary and integrated resulting in production of actionable forms of knowledge. Systems encourage willingness to act on what is already known and support learning from action. Emphasis is on know-how not just know-what or know-why knowledge. Research success is framed more in relation to impact on practice for addressing complex challenges in ways that are empathic to those involved.	Interconnected & inter-related, Science for all
Knowledge and wisdom are holistically integrated in the service of life	Knowledge systems integrate practical wisdom as core to their operation. They recognise the importance of moral/ethical judgments about why and how certain ends are pursued or not. This reflects Aristotle's idea of phronesis, a form of practical wisdom and knowledge where action and knowledge are oriented towards concern for human flourishing and viewed as inseparable. This has implications for valuing knowledge that is relevant and actionable, and for evaluating impact of knowledge production on practice.	Wisdom focused, Encompasses ethics and aesthetics
Freedom and trust to engage with complex issues, enhance creativity and learn from mistakes	Knowledge systems provide freedom and trust to actors to allow them to engage with complex, chaotic and uncertain issues. For example, funding structures (e.g. long-term vs short-term) and disciplinary norms (e.g. silos vs integrative) support actors working on complex and open-ended issues. Research cultures foster trust, creativity, and freedom of inquiry. As a result, actors are able to explore issues of high complexity and uncertainty without being penalised by failure or the long-term nature of sustainability outcomes.	Trust, High creativity
Reflexive and geared to advancing transformation	Knowledge systems encourage reflexivity among all involved, and allow the time and space needed for it. This is important for ensuring knowledge and action is geared towards transformational rather than incremental change. It includes, for example, attention to co-defining problems, questioning of taken-for-granted assumptions and reframing research and action. This occurs over both fast and slow timescales for addressing both urgent and longer-term problems in systemic ways.	Reflexive & responsible, Transformational
Supports self-actualisation and fulfilment	Knowledge systems allow actors to cultivate and respond to intrinsic motivations for self-actualisation and fulfilment. Knowledge systems allow actors to be their "whole selves", and encourage ethics, learning, and sense of beauty. This means that processes of research are viewed as more than matters of technical problem-solving or fulfilling external demands and recognise the need for personal transformations as part of knowledge production. This includes focus on quality and usefulness of the knowledge produced.	Encompasses ethics and aesthetics, Engaged and grounded, Widely informed
Polycentric, contextualised and experiential learning systems	Knowledge systems are organized in polycentric ways that are distributed (i.e. multiple centres of action) but also self-organising (i.e. with some coordination between centres). This allows the systems to be responsive to the contexts in which they are embedded, for shared understandings to emerge that synthesise context specific and general insights, and incorporation of diverse of forms of knowledge, including experiential learning.	Local & globalised knowledge
Global knowledge commons	Knowledge systems are a global knowledge commons, co-owned by humanity as a common resource. They are open and accessible in service of societal needs, and governed in ways that protect against private ownership at the expense of the public good.	Outcomes for everybody, Science for all, Egalitarian, equitable & inclusive
Worldview that values and attends to the interconnectivity of all life	Interconnectivity in all aspects of life is recognised that values connections among people and with the planet and which is founded on a worldview of complex systems. Sense-making is a key purpose of knowledge systems and complexity of the world is embraced as a living whole. Subjects of inquiry are seen as subsystems of larger systems, which can only be fully understood in their relationship to the larger wholes in which they are embedded. This worldview may draw on advances in complexity science, quantum mechanics, and long-established philosophies of wholeness (e.g. D. Bohm, J.W. Goethe, N. Haramein). A sense of re-enchantment with the mysteries of the world is invigorated.	Interconnected & inter-related
Education for lifelong learning and transformative practice	Educations systems in society cultivate a broad holistic view of knowledge and the development of transformative thinking, capacities and research. They promote lifelong learning that enables diverse members of society to participate in various forms of knowledge production.	Widely informed

Table 3
Contrast between the emergent properties of old and future knowledge systems, building on the identified challenges of old and the vision of future systems (Tables 1 and 2).

Old system	Future system
Fragmented & disconnected	Interconnected & inter-related
Globalised knowledge	Local & globalised knowledge
Narrowly informed	Widely informed
Avoids ethics and aesthetics	Encompasses ethics & aesthetics
Elitist, exploitative and exclusive	Egalitarian, equitable & inclusive
Self-referential & uncritical	Reflexive & responsible
Competitive	Collaborative
Fear	Trust
Observant & abstracted	Engaged & grounded
Low creativity	High creativity
Incremental	Transformational
Outcomes for a few	Outcomes for everybody
Science for science	Science for all
Knowledge focused	Wisdom focused

viewed knowledge as a common resource, co-owned by humanity and protected against appropriation and enclosure by narrow interests (Fig. 2, Table 2).

The emergent properties of the envisioned systems are a major contrast to those often experienced in existing systems (Table 3). Importantly, the two systems have different goal orientations. Rather than producing ever more *knowledge* about bio-physical and social phenomena, new systems need to be oriented towards developing *wisdom* about how to act appropriately in the world (Table 3). While there are many interpretations, wisdom tends to be viewed as including more than knowledge [74,78]. Wisdom involves being intellectually careful but also requires discernment, perceptiveness, imagination, and social and emotional intelligence [78]. While knowledge helps achieve a particular desired outcome it does not on its own take into account whether that outcome is right for a particular time, set of challenges, or needs of diverse people. A shift towards producing wisdom would require deep and fundamental changes in how knowledge systems are structured and supported and in how they operate within society. Yet such a shift is essential if humanity is to avoid catastrophic change, transcend the challenges created by past and current knowledge production, work with ethical and aesthetical aspects in combination with knowledge and to support emergence of more equitable and re-generative futures [79].

3.3. Domains of action needed to stimulate a pattern shift

Envisioning desired and idealized future systems is relatively easy. A harder task is identifying domains of action needed that specifically lead to a systemic pattern shift. Eleven domains were identified (Fig. 2, Table 4). These included: Connecting champions of innovation and learning about more radical forms of research and knowledge production; encouraging mass participation in, and more open forms of, knowledge production; scaling up, out and in-depth creative solutions and approaches to tackle seemingly intractable challenges; supporting a global knowledge commons to build a more transparent and egalitarian form of science; fostering safe spaces to experiment with new methods and ideas; and establishing supportive funding schemes, rewards and incentives to encourage new practices, appropriate cultures and for developing action-oriented knowledge producing institutions.

Finding ways to enact a new social contract between science and society was also identified as important. Here agendas, decisions and actions need to become informed by more democratic knowledge production, such as through genuine collaborations between citizens and *trans*-disciplinary scientific networks. This can be encouraged through greater focus on intercultural and holistic forms of education, developing practical wisdom and systems practice, and enhancing socio-

economic conditions to enable wider citizen involvement in knowledge creation. This highlights the tight co-dependencies between facilitating new knowledge systems and working towards more equitable and prosperous societies (Fig. 2, Table 4).

The action domains are consistent with many existing initiatives. Examples include global networks, bridging and boundary organizations that support collaborative and action-oriented work (e.g. Future Earth, AR+, td-net)[80] and greater participation in knowledge production through citizen science, journalism initiatives and democratic innovations like citizen juries [78,82]. Efforts are being made to ensure knowledge is free and accessible, such as by Open Knowledge International, Mozilla, P2P and Wiki Foundations, open source software, net neutrality rules and Creative Commons licenses. Citizens are being involved in decisions about research funding such as through crowd-funding sites like Experiment.com and industry and researcher collaborations incentivized through voucher schemes. Such innovations embody a respect for all people as makers of knowledge, value knowledge for agency and action, and employ creative practices to access different ways of knowing and thinking beyond the purely analytical and logical. In this way they open up space for further change, such as wider participation in decisions and purposes of knowledge production.

More widely, collaborative, problem-based, and creative approaches to knowledge production are also occurring, such as through the rise of Social Innovation Labs, (urban) Living Labs, Learning Labs, Transformative spaces, Real-world labs, Design Labs, Fab labs and hackathons [83–85]. These initiatives challenge traditional notions of what counts as 'research' and create space for more action-oriented forms of knowledge production. At the same time, changes in education, such as tendencies towards life-long learning and distance learning (e.g. MOOCs), the pioneering of new approaches (e.g. Forest Schools) [86] and new platforms for training in change-making (e.g. Ubiquity University, H3Uni) and transformative learning (e.g. transgressive-learning.org/) are becoming more established. Education is, in some cases, also increasingly incorporating ethics, indigenous knowledge, sustainability and creative practices in curricula or research [87,88]. Although less widespread, initiatives to bring in practices like mindfulness (e.g. Smiling Mind), complexity education (e.g. Complexity Explorer) and systems thinking (e.g. Open University's systems courses) are receiving more attention, contributing to development of both knowledge and wisdom about how to act in a dynamic world. Many organizations are also seeking to create wider enabling conditions in society for change, such as shifting people-planet relations through the New Economy Movement.

While there are many existing innovations related to the action domains, a critical challenge is how to ensure that such innovations are not used to improve existing systems and instead create space for more radical change. Many innovations, for example, tend to be small-scale, misunderstood or not widely practiced. They are often led by entrepreneurial individuals and social enterprises outside the support of the mainstream. As such, they can easily die out through lack of support or become co-opted [89]. Interdisciplinary research, for example, has been advocated for decades but has often involved realigning elite power bases in the face of change through co-opting language and discourses rather than resulting in deeper changes in the way knowledge is produced [14]. Similarly, public participation in science is also often used to support existing research practices as opposed to facilitating deeper emancipation of the public [23]. Despite moves towards open access research, the vast majority of public funded research is hidden behind a paywall of profit-making journals. These examples highlight that changes towards more egalitarian, challenge and wisdom-oriented forms of knowledge production will not occur without concerted and strategic support and action [90,91].

Fortunately, much is already known from research on systems change about the kinds of support that would be needed to realize the action domains. First, emerging windows of opportunity need to be

Table 4
Domains for policy and action to assist transformation towards future envisioned knowledge systems.

Domain	Description	Domain category
Connect champions and innovative examples	Many people are already working to champion transformative knowledge production and use in diverse areas, but those involved and their initiatives are not well connected. Momentum for transformation and transformative research would be greatly enhanced by connecting champions and examples of innovative practice.	Experiment, Build new systems
Initiate broad societal engagement in knowledge production through creative, critical mass participation	Broad, critical participation in knowledge production and use through creative modes of engagement and mass participation with diverse audiences is important for helping them to challenge accepted knowledge. Communication strategies for bringing knowledge to people need to be diverse and tailored to the audience. Beyond traditional written documents and media communications, e.g. knowledge can be brought to audiences through festivals, events and creative workshops that encourage participants to re-think accepted knowledge and support them to develop their own opinions.	Amplify, Experiment, Build new systems
Strongly embody creativity and agency in knowledge production	The longstanding idea that science is a purely objective pursuit can limit space for creative practices in knowledge production and agency in knowledge use. Meaningful creative practice is crucial to generate new insights and knowledge needs to inform action for transformation. Learners need to be exposed to creative practices and learn how to put what they learn into action as agents of change.	Experiment, Amplify
Actively foster a global knowledge commons	A global, online knowledge commons is already emerging through initiatives such as Wikipedia, Creative Commons and Open Knowledge International. This emerging knowledge commons needs to be actively nurtured, facilitated and democratised so that it integrates diverse knowledge sources and makes knowledge accessible in a transparent way. Participation in this process should be widespread and equitable.	Experiment, Build new systems
Create and foster safe niche spaces to experiment and learn from new forms of collaborative knowledge production	Protected niche initiatives play a crucial role in transforming knowledge regimes. They offer spaces where diverse groups can collaboratively experiment with new practices, use knowledge, learn about what works, and develop capacities for more transformative knowledge production. These niches will need to include safe spaces for dialogue across opposing views, help move towards mutual understanding across generations, ideologies or knowledge boundaries (e.g. disciplines), help establish more and stronger boundary spanning organizations and institutionalise arenas for collaborative partnerships across academic and practice.	Disrupt, Protect, Amplify
Restructure funding and incentives	Funding for knowledge production and use is not well aligned with community priorities such as the Sustainable Development Goals or addressing climate change. Funding schemes, including selection criteria, mechanisms and evaluation, need restructuring to support types of research consistent with these needs, such as trans-disciplinary, action-oriented and transformation research and innovation. New funding approaches such as crowdfunding could play a greater role.	Disrupt, Experiment, Protect, Amplify
Create a new social contract for co-production of knowledge and actions	Old modes of knowledge production and use in which scientists produce knowledge and policy makers act on that knowledge are giving way to new modes of co-production of knowledge that blur these boundaries. A new social contract is needed in which agendas, decisions and actions are informed by democratic co-production of knowledge in collaboration between citizens, trans-disciplinary scientific networks and policy makers to support more collaborative approaches to the production and use of knowledge. Citizens should play an important role in setting agendas, generating knowledge and making decisions, while scientists and policy makers need to better understand each other to work together productively. This in turn requires much greater opportunities for cross agency working, such as secondments for academics and policy professionals to work with each other.	Build new systems
Grow holistic learning systems and practices	Develop free, intercultural and holistic education systems for life-long learning that accept diverse learning approaches and systems, and value cross-sectoral, intercultural and trans-disciplinary knowledge. These need to promote: creativity; critical reflexivity; diverse knowledge perspectives; collaboration; pragmatism; mind-body-emotion, place, nature, science-art connections; and experiential learning.	Experiment, Amplify
Build literacy at all ages to work with complex systems	Learners at all ages need to build their capacity for systems thinking and understand the implications of complex system dynamics for practice. Complex systems exhibit emergent behaviour, so long-term adaptive projects and initiatives are needed to put systems thinking into practice.	Amplify, Build new systems
Encourage ways of learning from action that include agency and wisdom	Learning practices and education need to foster continuous learning rather than overemphasise achievement of specific output measures. Learning should be collaborative, operating through loops of collective action, evaluation, revision and further action. Teaching philosophy, experimentation and openness to multiple sources of knowledge is important to build the capacity of learners to take responsibility for their learning and ask and seek answers to wise questions.	Experiment, Protect, Amplify
Create socio-economic conditions to empower participation	Billions of people are not free to participate in knowledge systems due to their socio-economic conditions. Global reforms to abolish exploitative structures and provide fair access to income, employment and education are essential for such people to contribute their unique perspectives. Example reforms could include universal basic income, shorter working weeks and development of open learning organizations.	Build new systems

anticipated and embraced [92], such as appropriating new digital technologies to enhance greater engagement of the public in knowledge production and learning. Such technologies can create opportunities for novel business models and flatten knowledge production hierarchies if harnessed in appropriate ways [93]. Importantly, and at a bigger scale, windows can also arise from the current knowledge systems getting

destabilized, such as by public critique, scandals or a perceived decrease in functionality. These destabilizations can provide opportunities for alternatives to grow, influence and potentially transform the mainstream knowledge system.

Second, active support is needed for the domain of experimentation [94], such as through targeted funding schemes focused on developing wisdom not just knowledge. Research funders have an extremely important role to play in helping shape emergence of new practices, knowledge systems and paradigms [95]. Such assistance, however, needs to overcome inertia of current powerful self-referential peer bases while simultaneously continuing to nurture the extensive capacity and expertise of research communities.

Third, active protection and amplification of promising innovations [80,94,96], albeit with effective risk management, is critical. Such support can be diverse, such as spreading narratives that encourage systems change or encouraging new coalitions that stimulate actions beyond the status quo. Such work needs to ensure alternative voices are empowered and heard to facilitate evolution of formal and informal rules, norms, standards, routines and cultures of knowledge production [94]. Here, boundary organizations and institutional entrepreneurs that connect key actors of established systems with other voices are important [80] as well as approaches that facilitate integration of knowledge that specifically seek to empower marginalized knowledge holders [22,97].

Fourth, new support and organizations will be needed [98]. Complex societal systems tend towards path-dependencies and lock-in, such as arising from established structures, routines and dominant interests [99] and are on their own unlikely to actively re-invent themselves. Examples are risk averse disciplinary peer review systems that tend to support existing approaches. New kinds of infrastructure (networks, funding, incentives) specifically to support the scaling of new thinking and transformative initiatives are therefore critical [98]. An example are current attempts to establish new kinds of infrastructure to support transformative innovation, action and learning through the SDG Transformation Forum (https://transformationsforum.net/).

Finally, the action domains highlight that changes in knowledge systems will not occur without changes in related systems, such as education, finance, media, or legislature. The way different kinds of knowledge are emphasised or used are affected by such systems. For example, media drives particular narratives that have not traditionally called for systemic change and formalised education systems tend to focus on developing capacities for producing or working with certain kinds of knowledge. In short, for transformations in knowledge systems to occur, transformations in other systems will also be required.

4. Discussion

This paper has highlighted that action is urgently needed to ensure our knowledge systems become a much more creative force in supporting the continuation of life on our planet. Findings suggest we know much about what is needed and how to get there, including different value and goal orientations to what we already have (Table 3), and are consistent with other studies [27,67,100,101]. Compared to most of existing literature, however, our findings place a much stronger emphasis on the need for future systems to go beyond creating knowledge about the world to rapidly creating the wisdom about how to act appropriately within it. This finding is consistent with other philosophical analyses [102], and has largely been overlooked. Importantly, such a shift in goal orientation will require deep changes in knowledge systems, such as the way in which knowledge creation and learning occurs in and across Universities. It will also need to occur rapidly and at scale if knowledge systems are to keep pace with the scale and speed of planetary change.

Our findings provide five main messages about how transformations of knowledge systems might be stimulated. First, there is much important innovation around which further advances in transdisciplinary

and post-disciplinary methodologies can build. Continuing with methodological innovation and experimentation at smaller scales is important, but not in itself sufficient. Second, considerable efforts are needed to scale innovation so these pockets of the envisioned future in the present become the new system. Third, this will require new 'infrastructure' (institutions, support, and governance) specifically with transformational intent in mind. Fourth, this will require ingenuity and bold and strategic action to overcome resistance to change and strong path dependencies [103]. Some energy and climate research, for example, has strong links to fossil fuel-based economies and geopolitical interests [104,105] while existing compartmentalized structures are in themselves highly self-reproducing and powerful. Concerted efforts for change will thus require support from diverse government and non-government organizations geared towards ensuring creative disruption and that vulnerable groups do not become further marginalized.

Finally, deep assumptions underpinning knowledge systems will also need to be challenged. This includes the prevalent assumption researchers should and can be independent to what they observe and that knowledge creation is not an intervention [28]. While these assumptions have been part of the success of past and present knowledge creation, they have also limited development of approaches that are inclusive of more diverse notions of knowledge and knowing and possibilities for combining knowledge creation with ethics and aesthetics [15,57]. We do not suggest that all scientists need to be advocates and many important hallmarks of current knowledge production will need to be retained in new systems [15]. Yet there is an urgent need for greater consideration of how we - researchers and 'formal' knowledge producers - may be as much a part of the problem as the solution and how our own thinking and actions inhibit wider societal transformations. The door to what may previously have been considered 'sacred cows' that may blind us to other possibilities now needs to be thrown wide open.

This paper has been an attempt to open those doors. It sought to reflexively look inward to examine how we, as researchers and practitioners, can be more impactful in our outer world. This was made possible by viewing the research as being conducted as if from within the system being studied and asking how we might intervene within it. This allowed the integration of different forms of knowledge, including the 'truths' about current knowledge systems and how they operate as well as the normative 'truths' about what collectively was desired.

The approach, however, was not without limitations. Many pragmatic decisions needed to be taken to manage the large number of contributors and their input, which limited the extent of involvement of participant-researchers in research phases. The work also focused on a particular community where perspectives from the global south were largely absent. This creates a real danger of perpetuating existing colonial-based traditions and missing out important and more diverse notions of what constitutes knowledge, knowing and action. Input from science, technology and commerce were also poorly represented, which may have led to the virtues of current dominant knowledge systems being under-appreciated. Finally, perspectives of under-privileged members of society were absent. This has potential for the opposite effect of the value of current knowledge systems being over-estimated given that current systems are often viewed as primarily serving societal elites and being far removed from the coal face of under-privileged life. Thus, while extensive attempts were made to validate and appropriately represent the knowledge elicited, the findings primarily come from a particular cadre of expertise, albeit with extensive understanding of knowledge systems, societal transformations and 21st century challenges like climate change.

The findings may also be criticized for presenting a single coherent collective view that overshadows the more diverse subjective perspectives of participant-researchers. While such criticism is legitimate it would, however, be a misunderstanding of the approach. The three horizons map (Fig. 2), which emerged from a carefully integrated set of findings and extensive deliberation, is meant to be a broad guide to help

articulate and direct action rather than be one that shows all complexities [71]. The method is also meant to collate a diversity of perspectives in ways that show a set of emergent patterns about how a future vision might come about. For all its merits and limits, the map is thus a tool to help conceptualize and support maintenance of transformational intent. It is also intended to stimulate critical reflexivity amongst scientists, policymakers, practitioners and the public [106] about how knowledge systems can become more viable in the face of rapidly changing societal needs.

In addition to the findings about 'how' to support systemic change in knowledge systems, the paper raises important implications for research. While there has been extensive critique about methodological advances and broadly on knowledge systems, there has been very little about how transformations in them might be achieved. We thus call for a new kind of reseach field that actively seeks to support emergence of more viable knowledge systems for our rapidly changing world. This field would include exploring and showcasing a wide diversity of epistemologies, ontologies and pedagogies well beyond those usually considered in western dominated science and which embody the goals and values of envisioned systems. It would, however, also need to go beyond focusing on innovation of methodologies to having an active focus on supporting the kinds of transformations in knowledge systems that are needed to support wider societal transformations. Such a research field will, in turn, need to be underpinned by a second order and action-oriented approach.

5. Conclusions

Current knowledge systems are invaluable and many of the historical advances in knowledge production need to be retained. Yet, for all their brilliant success, they are not currently adequate for the new world in which we find ourselves. The philosophical challenge of learning how to generate knowledge has largely been solved [79]. The critical challenge now facing humanity is how to turn the enormous capacity of knowledge systems towards supporting development of wisdom about how to act in the world [76,107]. This represents a significant shift in goal orientation which to be achieved will most likely require the kinds of change of the scale and depth of the enlightenment. Importantly, such change is no longer a luxury or something that can be put off for others to deal with later. If knowledge systems are to meet the scale and urgency of global challenges and genuinely be a creative force for change for issues like climate change, then the pattern shift will probably need to occur at the pace of the scientific and technological revolution experienced during the second world war.

While the speed, depth and scale of such a shift is daunting, our findings show that much is already known about what needs to be achieved and how it could be encouraged. A staunch defence of global access to, and creation and ownership of, knowledge will need to be accompanied by rapid scaling of new transdisciplinary methodological innovations and support systems that genuinely blur perceived disciplinary boundaries and between research and action. Support will also be needed to help those seeking to do things differently step out of existing paradigms while deep underlying assumptions about what counts as knowledge and knowing will need to be surfaced and challenged. Governments, scientists and wider civic society all have an important role to play in helping this occur and responsibility will need to be extended to wider education systems and other societal sectors. Change will clearly need to build on past advances and the baby does not need to be thrown out with the bathwater. Yet, at a time of the sixth planetary extinction and a critical climate juncture, transformational intent will be critical to ensure we go well beyond improving existing knowledge systems to rapidly advance capacities for the generation of wisdom that ensures longevity of human life and other species on our planet.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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