Wicked Solutions: SDGs, Research Design and the "Unfinishedness" of Sustainable Development

ANN LIGHT

University of Sussex, Ann.Light@sussex.ac.uk

ERIC KASPER

Institute of Development Studies, e.c.kasper@ids.ac.uk

SABINE HIELSCHER

University of Sussex, S.Hielscher@sussex.ac.uk

ABSTRACT

The appearance of the UN's Sustainable Development Goals (SDGs) marked the first time a global body has attempted to manage the planet's future in its entirety, linking together urgent, overlapping and contradictory existential threats. The goals newly treated the world as an interlinked system, where relations are as important as components, and problems and solutions evolve together, acknowledging a more entangled trajectory for sustainable Development work. Through this lens, it becomes clear that all answers to how we live are provisional and shifting. Thus, we need more than new knowledge, products or policies from our research; we need to consider how different disciplinary efforts combine, take on life of their own, and nurture new configurations in a dynamic system. This paper invites us to rethink the making of viable futures, in the context of this reframed Development discourse, using design theory and approaches to complexity. It seeks to contribute by proposing HCI tools to manage the new uncertainties this introduces into the design of experts' research work. Using ideas of "unfinishedness" and the concept of "wicked solutions", it addresses the incommensurability and contingency to be found in knowledge-making and problem-solving, with an agenda of socio-ecological renewal.

CCS CONCEPTS • Human-centered computing • Human computer interaction (HCI) • *HCI theory, concepts and models*.

Additional Keywords and Phrases: **Sustainable Development Goals (SDGs); complexity; system; wicked problems; solutions; incommensurability.**

1 INTRODUCTION

The UN's Sustainable Development Goals (SDGs) offer 16 facets of sustainable future progress, with a 17th concerning *Partnership for the Goals*. Ambitions to address sustainable Development as a world system, rather than separate problems, have produced a new articulation of global challenges that fragments global social, economic and environmental futures into 169 subthemes, while uniting them in a totalizing scheme for the first time. This shift in conceptualization emphasizes new challenges for scientific research, inviting the world to think differently about problem-solving. The SDG framing fosters a sense of interdependencies in our global system at policy level, making a welcome (if late) response to climate crisis [66], in addition to inequality and poverty, and acknowledging global and system-wide need for change. These attributes suggest a change in focus for the knowledge practices of science [55] is overdue, since practices have become highly silo-ed during the 20th century.

This paper is ultimately about supporting science and other knowledge fields to embrace the relational qualities of solution-seeking at global level. It uses the SDG framing as a way to consider the theory and practice of problem-solving to meet the particular challenges of working on climate emergency–and reflect on characteristics that might be useful in the design of tools. It uses the SDGs because of their global policy significance, but also because they hold the paradox facing all science in the post-normal era [47,49,102] – we can only tackle details at any time, yet we must hold the whole in focus throughout.

We include our own HCI practices in these concerns, e.g. [15], but principally those of other social/science research disciplines contending with the immensity of what needs to be done (and done in concert, without a clear destination) to restore socio-ecologically sound futures to the planet. Informing this broad mission are three conflicts, highlighted by the SDGs:

- 'sustainability' is a problematic concept for denoting a future of increasing and unpredictable change;
- world Development[1] ambitions are contradictory in their nature and outcomes, within and between nations and regions;
- the expert teams needed to address future Development reflect these contradictions, bringing together a wide range of incommensurate knowledges, often with little training in interdisciplinary working (and none in design theory).

1.1 Debates in "Sustainability"

The SDGs are goals for sustainable improvement, with ambitions for climate action, life on land and in water (SDG13-15). They address more-than-human concerns, in that they address life beyond humanity and futures beyond our own. They do not, as such, address "sustainability". The distinction is important, since debate is rife as to whether "sustainability", the act of sustaining our current system, is possible or desirable. Answers to this question reflect the fast-changing state of the climate, soils, atmosphere and other dimensions impacted by the Anthropocene and our growing knowledge about these trajectories, alongside beliefs about whether mitigation and/or adaptation are possible (e.g. [12]). But they also reflect questioning of what is to be sustained. The planet will remain; humans are likely to exist in some form [139]. Few people want current extractivist and exploitative systems. Present levels of destruction require restorative policies, not sustaining. This debate has fueled the field of "Sustainable HCI" (SHCI) (e.g. [16,17,56,57,75,81,88,96,123,131]), which

[1] 'Development' written with a capital D means change for flourishing, not making software.

has slowly [34], then firmly rejected tools for tweaks in lifestyle as insufficient and now proposes plurality of approaches [91] and system change [75], arguing for new political [75] and economic structures [95], some in the context of potential collapse and scarcity, with whatever comes after [88,131]. SHCI is a militant branch of HCI, going beyond the structural politics of human relations to address existential concerns of who and what will survive the current levels of abuse meted out by capitalism [57]. It is a branch that questions the use of carbon for computing, even as it looks at what might justify digital applications towards socio-ecological ends.

This paper aligns with those in SHCI (e.g. [17]) and interaction design (e.g. [99]) seeking to change processes from the ground up. It supposes that change is coming from many sources, including popularism and the rise of isolationism and the Right and (we hope) more enlightened policy, as well as from a destabilized climate and the Global North's dramatic resource overuse. We take a particular tack on this, looking at the phenomenon of change itself and the knowledge needed to adapt to it. We heed a 2014 call from Silberman et al to '*Move beyond simple models to grapple with the full multi-scalar complexity of "wicked" sustainability problems'* and '*Draw from and support relevant work outside HCI'* [123], developing the reflection that a systems approach is needed [75] and fleshing out what that might mean. As authors, we do not know what digital tools will function in a few years, particularly as networks become more centralized, thus without the resilience of distributed systems. Uncertainties are increasing; industrialized nations have little track record in working flexibly–there has never been a time for them during the era of computing in which upheaval was a constant[2]. We cannot guess what we are designing toward, but that should not stop us making mindful use of existing resources to increase our future options and plan for greater uncertainty.

We do know that all living beings will depend on good research for survival as change speeds up and also that little has been said about how we look after knowledge as the planet changes. So, our priority here is to address *lack of closure* in research, challenging "sustainability", in that neither social nor environmental conditions will persist[3]. We consider "unfinishedness" in knowledge projects as an intrinsic part of a more relational approach to knowledge-making [58,125,127]. And we address the types of interactive tool that might support specialists, in this more tumultuous context, working to make the world safer and restore/renew it for life and living.

Hazas and Nathan [93] identify the SDGs as a new force, despite contradictions. Within design scholarship, there is a call for more research on their impact [41] and guidance that, while the SDGs 'are helpful for establishing research goals, they are not complete solutions to evaluation' [109]. Here, we draw on Cairns et al's design study on projects at the intersections between the SDGs [26]. We also recognize a wealth of Development issues being addressed by sociotechnical work (e.g. [1,3,7,30,32,54,67,114,134]), in contexts of the underserved (much in the Global South). Digital tools 'intervene in the longstanding and complex sociopolitical and economic issues related to international development' [10:80] and interaction designers have long deliberated on how. We diverge from this work because we understand the SDGs to have reconceptualized the nature of Development to put a focus on quality of life for all. We believe that a new understanding of Development invites new classes of tool. This focus on quality of life for all is one of the

[2] Noting that many 'developing' regions have been living with greater instability from the climate and the effects of colonialism.

[3] Caught, in part, by speculation: 'Climate change won't result in a new normal but in constant, horrifying new disasters' [103]. See also [142].

most significant aspects of the SDGs and one that has not found its way into HCI (for) Development (HCID) discourses as yet. If we think in terms of *sustainable* Development, we are no longer in the era of post-colonialism and techno-Modernity, but must recognize that many Global South and Indigenous scholars lead the world in their reasoning [113,122], even as the wellbeing of Global South regions and Indigenous nations has been marginalized. Therefore, design for Development is something we need to train upon the failures of the Global North. In this paper, we thus bring two strands of HCI research together – showing that HCID and SHCI are not separable in a world that fully acknowledges the interdependencies of our pluriversal and entangled globe [8,42,60,89]. This is itself a political act, but we are more concerned to show the fall-out of these reconsiderations.

1.2 Contribution

This paper brings a planetary Development policy initiative into conversation with the ambitions of researchers addressing climate change, the Anthropocene and quality for all life, then suggests how this can be supported by interactive systems that incorporate these existential concerns. We use the reframing of Development in the SDGs to discuss what is needed to 'stay with the trouble' [60] of working in a world system, linking this with design theory on problem solving. We give some background on the SDGs, particularly the 17th goal, which is *Partnership for the Goals*, linking the ambitions of the Goals to systems theory. From there, we propose some characteristics of tools to help support the development of contingent (i.e. wicked) solutions, as a way of taking research practices forward in mounting uncertainty. Given an argument for "unfinishedness", we offer prompts, rather than specifications, in pursuit of fluid outcomes that 'capture the new complexity and multiple criteria for what must be delivered' [82]. We conclude by speculating on what is needed to bring HCI concepts into discussion with these global movements.

There are a number of different knowledge traditions brought together in this paper, to offer: 1) a definition of 'wicked solutions' that helps draw attention to 2), a process for addressing knowledge creation in the context of the SDGs and living with rapid, increasingly unstable, change, so that the value of 3), types of tool that sustain the "unfinishedness" of solutions, becomes clear. Since this relies on so many domains, we present this quick overview of the fields we draw on, before attempting to synthesize them (as far as is possible and meaningful) in the following pages:

- HCI and Design Theory, showing how design knowledge interprets relations between problems and solutions and, relatedly, the use of "unfinishedness" in designing;
- Sustainable Development, considering the incompatible ambitions and joined-up thinking at planetary scale of the 17 Sustainability Development Goals as a welcome policy replacement for Development work that sought only to address poverty and economic growth, without attending further to histories of colonialism or the needs of the planet;
- Feminist Techno-science, providing visions of interdependence, plurality (including diversity of ontologies) and entanglement to challenge dominant scientific discourses;
- Systems Theory, drawing attention to the dependencies that weave together impacts, indicating that outcomes are not predictable and emerge through perturbation rather than deliberation;

Ultimately, this discussion about making scientific knowledge has the practical end of providing suggestions for how interactive tools might support doing so, but much of this paper is devoted to setting up the theory that shows why these types of tool would contribute to the renewal and regeneration of our planet's living

conditions. Unlike much HCI for Development and for Sustainability, where empirical studies reveal what is considered to be a clear mapping between problem and device, the relationship between the topic and the tool here is mediated by a greater slew of evolving political, social and epistemological issues. It is this complexity that we discuss in the paper and that, overall, as specialists working together on evolving complex problems, we need to discuss more.

2 PROBLEM-SOLVING AND KNOWABILITY

What might we find in existing design theory to reflect on solving (and not solving) problems? *Wicked problems* (e.g. [80,145]) and critique of thinking in terms of solutions [38,111] already inform HCI and design. For instance, Encinas et al [39:1] offer the following related insights: (i) socially engaged HCI problems are intractable and uncertain; (ii) the purpose of much HCI and design research is not to solve a problem, but to understand the problem; and (iii) problems themselves are constructed and framed by researchers and so necessarily reflect the specific values, interests and the analytic tools available to them. Nonetheless, complexity in designing is often seen as a problem to be reduced [70,101]. There is a heritage of trying to *fix* things, not manage them. For instance, Kolko distances himself from the argument that truly wicked problems do not have solutions, but only appeasements. He says 'I think we can best these problems, specifically because we've created them. … it's with a human and humane mind that we can both explain and, ultimately, fix the problems that exist in our culture and society' [4:80].

We suggest that current issues take us beyond our cultures and societies and beyond the linearity that links problem and solution. It is not clear where they take us. What we do know is that tools – and here we mean technologies broadly, but also the digital – will need to do things that are unknown *a priori* and address a range of evolving and interdependent concerns. The SDGs neatly encapsulate this difficulty. To understand this tension better, we next turn to how solving problems has been understood as part of design theory and what is changing.

2.1 Wicked Problems and Beyond

Solutions began to receive serious theoretical attention in the 1960s, connecting the methods of design to 'models of problem solving in other fields' such as science [33:4]. During the 1970s, design research developed in reaction, with Rittel and Weber suggesting 'design problems are ill-defined, ill-structured, or wicked' [44:682]. The idea of *wicked problems* [19,110] took hold and it was eventually argued that no design problem is less than wicked [27].

Wicked may seem a gothic term, but here it implies a class of challenge. Climate change has been called a wicked problem [45,75,123]. In fact, in the ecological humanities, Morton calls global warming a '*super wicked problem*' [94:36] drawing attention to five wicked attributes. It is:

- Irreducible and difficult to conceptualize and anticipate;
- Unverifiable: 'if we "solve" global warming, we will never … prove that it would have destroyed Earth' (p36)
- Uncertainly interminable: there is no way to predict when different factors will cease to function;
- Alogical: 'solutions cannot be assessed as right or wrong, but as good or bad' (p37);
- Irreversible: there are 'no trial runs, no reverse gears' (p37).

He concludes that there may 'be no way to solve a wicked problem neatly and know that we have solved it' (p37).

This thinking is in line with how design theory has reformulated problem-solving. Dorst argues that creative design is 'a matter of developing and refining together both the formulation of a problem and ideas for a solution' [33:10]. Over time, possible 'bridges' emerge between problem and solution that are described as 'unstable' and 'temporarily fixed' [33:10]. Tatar conceptualizes design as '*goal balancing*' rather than problem solving, working with '*design tensions*' and '*incommensurate dimensions*' [129:415] - these conflicts need handling via compromise and reconciliation. System-oriented design [120] helps designers tackle problems in the round and generate 'holistic resolutions from complex project information' or 'synergetic responses' [120:2] - questions include what role open-ended design or designing for the unexpected could play, where a product is not static, but *unfinished*, meaning users can change it over its lifetime [121:10]. Tonkinwise [132:113] explores ways of rethinking design processes: reframing problems; problem-finding (design research); problem-making (critical design, discursive design), all implying an "unfinishedness" to both the problems and the solutions that emerge as counterpart. A parallel journey in HCI is partly documented in Harrison et al.'s [62] analysis of the field's paradigms.

Concern about the nature of the questions being asked has gained traction with expansion of the designer's role [90]. Emilson et al. [37:24] argue 'there has been increasing interest from designers in applying their skills on social issues … responding to the negative consequences of industrial production, mass consumption and the breakdown of welfare models'. Transition design [68] offers multi-stage change of practices. It embraces 'globally-connected place-based approaches, the amplification of grassroots initiatives, and designing for varying horizons of time and levels of scale' [77:1]. Light's pluralist social innovation takes this to an extreme, with an approach to 'sensitizing and attending to, not solving' [85:18]. The new objective in these accounts is to act collaboratively to create conditions for change, rather than provide solutions.

The transition design framework is particularly interesting since it intends the 'kind of designing that "stays with" a problem' [133:89], reminiscent of Haraway's *staying with the trouble* [60]. When Irwin [68] proposes that a first task is to enable stakeholders to arrive at an understanding of the complexities and interdependencies of a shared problem, we see a glimpse of what *staying with a problem* might entail. And the body of work coming from feminist technoscience, led by Haraway and Barad, sees 'trouble' less as a problem and more as a way of encountering an evolving, highly contextual and entangled world (e.g. [63,85,111,130]). *Staying with the trouble* means 'following emergent questions and tensions', involving subtle analytic shifts toward 'thinking with design' [111:60] and letting things develop. Across these practices is a tension between staying open and delivering an outcome, and between acting and *cultivating emergence*.

2.2 Unfinishedness in Design

These positions are attentive to "unfinishedness". And this interest in openness manifests beyond the theoretical level. A weight of design research holds the design space open: objects are trialed in households where development of meaning is tracked over months [53]; design travels beyond making into use with *design after design* [108]; *meta-design* [36]; *unfinished things* [132:28] and *continuous design and redesign* [71]; even if, in business discourse, *eternal prototyping* (e.g. [138]) is something to avoid. Uncertainty can help produce 'new and open ways of understanding, making and imagining' [104:5], calling to mind design ambiguities [53]. Design theory has embraced plurality [85], hybridity [42], agonism [14], entanglement [8] and

care [106] as modes that refuse closure. These acknowledge the vulnerabilities, tensions and uncertainty in futures thinking, though, often, the horizon of the futures remain limited [5], even while the current crisis asks us 'to address problems that will take dozens of years or even decades to resolve' [68:2].

2.3 Methodological Uncertainty

The absence of closure in designing is amplified if we adopt Barad's methodological theory of the agential cut [8], accepting that our tools and methods make our research findings with us and that we cannot know our world without this mediation. How we cut through our world will influence what we learn. Our instruments shape our findings [64]. Thus, we construct data, rather than discovering them, through entangled tools and questions. Accepting this requires us to let go of any epistemological certainties along with ambitions to solve problems. We see that situations look different depending on what tools we use to establish their characteristics. Designing science is like designing other products: absolute knowledge and measurement are impossible, even with our best tools. There will always be uncertainty, both epistemologically and methodologically. Noting this, we can also see how our tools might reflect this lack of certainty or, alternatively, force closure where none is called for.

2.4 Concrete Designing

In the previous sections, we have described trends towards uncertainty in design theory and research methodology. Both open up solution spaces alongside problem spaces and offer ways of thinking that resist closure, yet they may still underestimate unknowability in their conceptualizations. And, at project level, there are practical reasons for reticence - such qualities make it difficult to execute design processes, particularly in the current context of finite budgets and expectations of efficiency. Lack of closure is as much a weakness in practical terrains as it is a virtue. Domain experts responding to global challenges – and intersections between them – are running Development or research projects that require deliverables. They need to show competence in delivering: to acquire funding, satisfy funder conditions, and share insights with colleagues. Just like many designers, they are concerned with achieving a recognizably productive outcome within timeframes dictated by others. There are urgent conditions that need attending to and moving towards "unfinishedness" does not seem a good strategy.

And, despite uncertainty, outputs are necessarily concrete, not perhaps in terms of their materiality, but in terms of their specification. There is a tension between staying open to evolving meanings/conditions and arriving at workable knowledge/products, by which time many of the paths that could have been taken have been foreclosed. When we design a research process or build a technical system, it is intended to achieve an outcome; teams cannot indefinitely defer delivery while incommensurate and evolving elements are negotiated, even if the output is understood to be in permanent beta.

In other words, Development research tends to exist within a particular problem framing at any time, even if it is obvious there are contexts in which these framings are more or less plausible. Moreover, the outputs of the process depend greatly on who/what is considered relevant as a stakeholder and on how broad a system is understood to be influential in a particular case (e.g. [86]). Consideration of all the world's stakeholders (including future generations) and reconciliation of their perspectives may be the perfect ambition [68], but it is unachievable in practice.

In observing these tensions, we also recognize it is difficult to stand against institutional norms, as well as traditional mindsets, in responding to products, processes and outcomes that are uncertain, open-ended, and contested, i.e., unfinished. It is a professional and disciplinary challenge to act collectively to create conditions for change rather than applying straightforward solutions to straightforward problems. “Unfinishedness” may be needed to address current challenges in the round, but this is largely outside the training of the specialists coming together to handle intersections in knowledge, including different intellectual starting points and diverse systemic effects. So, our practical challenge is manifold: it is not merely thinking more relationally, but managing the impact this has on deliverables, careers, expectations and lives, all in tension with what a scientific training prepares a person to think and do.

3 THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

We reflect on these challenges in the context of a major change in Development policy. In 2015, through negotiation on the Post-2015 Development agenda led by the United Nations and set out by the Open Working Group on SDGs, the 2030 Agenda for Sustainable Development titled *Transforming our World* was adopted by 193 countries of the UN General Assembly. This laid out 17 SDGs and 169 targets [136] that turned the focus of Development from overseas aid to global wellbeing. Although not legally binding, the UN 2030 Agenda is intended to influence governments worldwide to turn the SDGs into national policies and targets [51]. The SDGs were considered to have ‘the potential to become a powerful political vision that can support the urgently needed global transition to a shared and lasting prosperity’ [55:7], though slow progress on the goals and increasingly evident contradictions have lessened general optimism. Even in this statement of potential we have the ambiguous term ‘prosperity’ and see that, for many in Development, ecological balance is still outweighed by concern about economic balance.

Historically, countries had their own goals for wellbeing, higher growth, etc., often designed for them by whoever lent them their debt, such as the World Bank and International Monetary Fund. Beside these were the Millennium Development Goals (MDGs), which, though global, focused on ‘developing’ regions [112]. A significant change between the MDGs and the SDGs is that the embedded notion of Development has evolved away from a patronage model.

The SDGs no longer assume the transfer of knowledge and funds from Global North to South or ignore other lifeforms. The *Modern* approach to policy has long been to take a linear view and aspire to progress [126]. This is now in transition, with some aspects of the SDGs more radical and others still speaking to progress of the economic kind, rather than the targeted growth for poorer areas that comes with aspiring to environmental justice. Some goals are couched in traditional Development terms: *Zero Hunger* (SDG 2) is presented as a lack, rather than safe and sustainable production, balanced distribution, sufficiency and suitability, of food [61,141] and remains human-centered. But now this is no longer conceived as something that poor parts of the world must achieve to be in line with industrialized areas. Instead, it is a world response to planetary issues [112].

Importantly, overall the framing requires researchers to think beyond individual--if substantial--problems (such as tackling poverty) to *linkages between problems* in a world system. This changed discourse for global conduct--the UN as a quasi-government setting out a planetary mission--offers a totalized and systemic vision of world Development as a single framing for action: a global design challenge for a better system. Furthermore, this invitation for global concerted improvement asks what it means to work with intersections

and tensions (as environmentalists and ecologists have been doing for many years), and what this means for the actions of making change. Does the new conception go far enough in connecting how we understand the world and make knowledge in it with the Development activities needed to renew it? We can ask how HCI and design theory might help extend the value of this new conception.

3.1 SDGs and Wicked Problems

The SDGs represent complex, dynamic interactions among factors such as food, water and justice, with no single root cause to address, making these collectively, in design language, an elaborate wicked problem. The new framing emphasizes how wicked problems are recreated and reinforced by the functioning of global systems that are indivisible. The framing--of 17 interconnected goals--has made the politics of knowledge yet more complicated. The goals are not problems for solving, but a vision of fair and fulfilling life on Earth. They hold the contradictions of every competing aspiration and incompatible aim. If we are not just to respond to crisis, but aspire to global fairness and fulfillment, as the SDGs do, then the world's wicked problem is all consuming. Although there are trade-offs and complementarities among the goals as they are described, at heart they point to interactions that go beyond such negotiable outcomes.

So a key feature of the SDG framework is that the SDGs do not define problems, as the MDGs did, but imply a disparity between current global realities and what 193 countries take to be desirable conditions. This disparity provides an invitation to scope problems, but which and how is not clear. When the global Development ambitions are laid out, the SDGs make apparent the impossibility of achieving all that governments promise. By presenting ambitions rather than pathways, the goals acknowledge that, while there may be consensus on the vision of a better future, there can be no consensus on the priorities or the preferred ways to bring about change. There will be winners and losers, and there are no clever compromises that could help us avoid the fundamental incommensurability of our various preferences, needs, or ways of making sense of the world.

This wickedness emerges, as noted, from the functioning of systems at planetary level (for instance, how a the reach and management of a river basin can affect water rights, which then can affect international politics, which, in turn, may affect the future of the river basin and so on). It is exacerbated by plural ways of knowing (e.g. eco-feminism [140] and Indigenous Knowledges [113,122]) that propose their own realities (e.g., contrasting perceptions of how food is valued). So responses must engage with complexity that is partly material (rivers, water rights, food) and partly the associated differences in how knowledge is built and different ways of knowing and ideas of what passes for knowledge. In a pluriverse [42], a world where many worlds count, there is a recognition that unaligned realities can and must co-exist without epistemic violence [42], but that different conceptions have agency and can, in fact, influence each other. This level of social interaction is as much part of acknowledging interdependency as any intra-action of material and tool and research method, to use Barad's term for the lack of separation between instrument and effect [8].

Even exploring a seemingly small topic (such as the sustainability of coffee drinking [anon for review]) reveals how far anything can be analyzed in terms of relations between goals and how many facets of life are involved, showing anew the interrelatedness of 21st century systems (e.g. [135]). Any (food) product can act as a prism on these relations, as Tsing demonstrates, pre-SDGs, so well with a mushroom [135]. This propensity of topics to spread, morph and reform meets design theory's criteria for characteristically *wicked*.

3.2 The Problem with SDG Problems

In looking at the SDGs, one could argue that nothing has changed with their re-representation of planetary issues since 2015, but the fact that so many governments spent so long arriving at this mapping is a case for their potential potency. Making a representation framework for sustainability goals is inherently political [119,126]. There is choice 'about how to define the system, about what system functions and outcomes are important, about what is to be done to make things better, about what "better" means' [115:73]. The SDGs, as prioritizations [18], have embedded hierarchies and relations, making things visible and obscure. They offer a stimulus to think at a global level about local, situated, yet interconnected concerns. While not capturing the symbiosis in/between systems that the popular *Staying with the Trouble* [60] brought to public awareness a year later, both are part of a conceptual swing to systems thinking.

But, with little clarity and some skepticism as to how the SDGs (and synergies between them) could be realized [84:1], trade-offs between goals have dominated discussion [50,65,98]. This is not surprising when knowledge is seen as a product of multiple rival approaches and silo-ed production. Yet, trade-offs are all too obviously not solutions. (An example of a synergy is linking *Quality Education*–SDG 4–and *Gender Equality*–SDG5–and noting the number of girls denied schooling across parts of the world – and further, that a rise in women's education is the most effective way of slowing population growth [2,78,97]. A trade-off would be accepting that addressing women's education increases community prosperity, which might mean more air pollution, etc.). Trade-offs, such as accepting that economic growth (SDG8) is necessary and modifying climate action (SDG13) accordingly, allow problems to be addressed in the usual paradigm. When there is fundamental incommensurability in our efforts, simply looking at trade-offs is insufficient.

The most obvious incompatibility is this contradictory demand in the goals. In line with SHCI (e.g. [95]), Spaiser et al [124] point to economic growth and consumption goals as underlying the main inconsistency. They specifically model how friction exists between SDG 8 (*Decent Work and Economic Growth*) and others, like SDG12 (*Responsible Consumption and Production*), SDG 13 (*Climate Action*) and changes to protect life in cities, air and water (SDGs 6, 11, 14, 15). Spaiser et al's models suggest there are factors that can contribute to Development (health programs, government investment) and ecological sustainability (renewable energy) without triggering conflict between incompatible SDGs, but conclude 'the SDG agenda will fail as a whole if we continue with business as usual' [124:457]. This is a powerful argument for trying to keep more factors in play for longer, rather than settling for compromise.

Yet, we note that to achieve this insight into correspondences, tensions and the drawbacks of compromise takes considerable work (and perspective) in itself, is still modeled on assumptions about how crises will develop, and requires expertise in fields serving different goals. Thinking at this scale and working at intersections between, rather than within, people's areas of knowledge relies heavily on cooperation and mutual understanding. Nerini et al. [50:13] suggest that transdisciplinary collaboration is key to 'understanding the interactions between disciplines and diverse actors'. This means that re-representation at the macro level requires other, more local, changes.

3.3 New Policy for Uncertainty?

So, how might researchers live with incompatibilities until better responses can evolve and policy can catch up with the impacts of crisis? One of the major arguments that Scoones (drawing on Rebecca Solnit in [117:15]) makes in attending to uncertainty is how uncertainties open possibilities for action. If it cannot be

known for sure what will or can happen–if it remains up in the air, yet to be determined by a range of factors–then any of us (in any configuration) have a chance to make a difference. The factors we can work with may be able to nudge other factors in the right direction; and if the outcomes are also open, then we can dream up and create all manner of new possibilities. Uncertainty opens up possibilities for agency. Policy that sufficiently works with uncertainty must acknowledge interdependence; if whatever anyone does can make a difference, knowledge-making and sharing cannot be an elite, predictable or controlled activity. The SDGs, we have shown, usher in a change for Development policy. What these new political expressions also implicitly reflect is dissatisfaction with previous, segmented, policy-making and, particularly, its handling of uncertainty. Just as Nerini et al. [50:13] suggest that transdisciplinary collaboration is key in research, so Nilsson et al. [98:20] call for policymakers to stop working in silos. These divisions are not only inadequate, but are now acknowledged to be inadequate. Scoones and Stirling [118] sum this up well:

> Conceived in narrow, technical terms, informed by relatively homogeneous, specialist views, these core organising ideas for high-level global policy-making typically emphasise aspiring control, asserting romantic visions of visionary leadership, heroic expertise, deterministic systems, orderly values, convergent interests, compliant citizens and expediently predictable futures. As a consequence, some highly uncertain issues that should remain open for political debate are imagined in circumscribed, biased and one-directional ways. The loudest voices and most powerful interests thus come to enjoy a disproportionate influence in defining what is meant by 'progress' [118:1–2].

The SDGs can act as a sense-making device in this context--both a context of persistent faults in policy-making, including science policy, and that of considerable consensus around the need to acknowledge and work with uncertainty more fully. *Partnership for the Goals* (SDG17) considers how teams come together to address the Goals and enshrines collaborative working. While interdisciplinary research and Development is not new, interdisciplinarity is given another boost with this, becoming more prominent as a research requirement.

Unfortunately, this emphasis on working together comes without accompanying evidence of increased skills (e.g. [26]). Expertise through the 20th century has been shaped by discipline, each field having its own ways of generating knowledge about the world (epistemology), worldviews (ontology) and defined methods refined for operating in specific domains. These priorities and worldviews are now embedded in scientific structures and disciplines, and echoed in universities and research centers, forming a basis for a segmented research culture that seems alien (and unhelpful) to designers, who are used to bringing together many types of knowledge. Moreover, these silos have no place in a rapidly changing future. However, there are legacy issues, such as hierarchies of knowledge ("hard" science is normally considered more serious than social science and the humanities) and other, even more intractable, issues. Epistemologies may be contradictory, while different ontological positions and different responses to encountering this lack of alignment (e.g., see postcolonial literature such as [67,128]) play out even in team meetings. The 17th goal, *Partnership for the Goals,* speaks, at least notionally, to the ontological, epistemological and methodological challenges in bringing partners in a wicked problem together.

In other words, experts acknowledge that they have to work together, but are still not clear about how to do that. Funding models and department structures appear to assume that it will happen in a straightforward way, but this is at least partly false. As a microcosm of the global wicked problem, there is fundamental uncertainty around how we can work together to achieve the goals. This is a challenge in responding to

uncertainty, yet we take heart from the existence of a goal that addresses the requirement for collaboration and understanding. It is building on this goal that we go on to consider possible ways to approach collaboration and understanding in implementing HCI tools.

4 FROM MACRO TO MICRO INCOMMENSURABILITY – AT PROJECT LEVEL

If we now look at some research topics that set out to consider intersections between the goals we can see some of these challenges at play. At the level of defining a project to work on (what we might call intermediate – between macro theory and day-to-day enactment), the scoping of a problem offers clarity of objective, but, at the macro and micro levels, clarity may quickly disperse because multiple ways of caring, knowing and researching are in competition [26]. Not least, 'Despite its discursive prominence, interdisciplinary working remains the exception rather than the norm in …practice' [26], in part because of this increasingly narrow specialization and disciplinary fragmentation [26].

Cairns et al [26] studied work at the intersections between SDGs, following scientists and social scientists working together on a series of explicitly interdisciplinary projects designed to look at SDG synergies and trade-offs. The projects they detail [26] are specific yet interdisciplinary, newly merging specialisms in discussion with new stakeholders, while, at project level, sounding no different to the kind of work run before the framework:

- Analyzing how external intervention is shaping collective action among rural households in India;
- Exploring the role of large herbivores in community connected agriculture, conservation and rewilding in south England;
- Applying a bio-social approach to examine antimicrobial resistance in Cairo, Egypt [26].

These demanding themes, with many intersections across the SDGs, were narrowed down from inception onwards. This was in order to deliver useable research (primarily, at this point, to find more funding so that they could act on what they were finding out). And Cairns et al [26] report that little mention is made of the SDGs and the goals chosen as a focus, despite being set up and funded to address intersections. But we can develop the last example, here, and situate it in a bigger picture. There are immediately many questions: how does this project on microbial resistance in Egypt link to the one after it, to ones near it or those in a neighboring country? What does it mean for hospitals (health, institutions), schools (education), drug companies (innovation, profit), hand-washing (public health), lawyers, etc. What does it mean for climate action? The tension between designing for personal health and environmental goals has been captured elsewhere [79]. As noted before, any issue pulls all of the SDGs after it, in different constellations--the way that the global system is both interdependent and fragmented makes each project a fractal of the whole and this extrapolation is merely one example of how any of these and other projects could be situated.

4.1 What This Tells Us

These concerns reveal that openness is very necessary when trying to tackle these intersections; the projects are about problem-scoping and situating as well as problem-solving and must tackle this without the orthodoxies of discipline. Researchers have always collaborated to share knowledge, but this puts a focus on the way all knowledge projects live in multiple universes, feeding into others and fundamentally changing them. There is a need to hold "unfinishedness" in play in working out the nature of the task. In these contexts,

designing is no longer a case of combining specializations but of trying to hold competing meanings stable long enough to make a claim and contribution and feed this into an evolving context.

This means that what was just of theoretical concern before the SDGs shook up global policy, is now playing out in transdisciplinary research and development projects, created by new national-level pots of funding. Meanwhile, different lenses bring different needs to the fore, but little exists to help navigate between perspectives. Cairns et al [26] note the teams were not prepared for this level of negotiation between types of understanding, where, at a macro level, competing, and sometimes contradictory, ambitions are all part of a single agenda and, at a micro level, different expertise is needed depending on theme and its orientation to these interrelations. Further, the macro and micro levels are closely coupled: the way that intersections are interpreted will change who is in the room discussing them and vice versa.

4.2 Resistance to Disaggregation

At this point the reader may be asking why it is not possible to use the time-honored process of breaking a problem into multiple problems. Could it be that breaking things down works to undo the contradiction and incommensurability that we are drawing attention to? Are we not merely complicating matters? Why approach macro (global relations) and micro (methods and priorities) together?

However, that is to ignore the wickedness in this agenda. This hinges on the difference between a complicated issue, which can be broken down, and a complex one, which cannot. Addressing small parts of the system at any time may be efficient to produce serviceable change, but any change is introduced back into the system, contingent on the outcomes of other events and with its own knock-on potential. This will not address issues that include dependencies.

Considering impact in/on/as a whole system means recognizing feedback loops and interdependencies in the system and, thereby, also acknowledging that picking off tractable bits is not dealing systematically with the bigger picture; rather, it is ignoring it. The single most important global political development caught in the SDGs is a reevaluation of interconnectedness; breaking down issues ignores this achievement. Instead, we might consider systems, system effects and how problems are encountered by system theorists more closely [123]. This does not have to be the only mode of operation, but it is a new mode of operation for many Development research projects [23,24,73]. And it invites us to consider systems research alongside HCI, before looking at tools to support these intersections.

5 LEARNING FROM COMPLEX SYSTEMS RESEARCH

Related to design theory is the body of work on complexity. James et al [69:23] say complexity has properties ‘making a situation or set of relationships difficult to discuss accurately, even when given almost complete information about its component parts and their interrelatedness’. In design, complexity is regarded as ‘non-normative, illogical, evolutionary, rich and diverse, unstable, unspecified between the two poles of a contradiction, never reaching exclusively one or the other ...tuned into at least two reality levels’ [31:130]. Zamenopoulos and Alexiou [143] review design and complexity in research, suggesting that complexity appears as a problem or a characteristic of design systems and artifacts; but also ‘as a *methodology* and tool for designing; and as a *theory* for understanding and defining design’ [143:96].

Complex systems are often associated with the tools of computational modeling, having the processing to go beyond human reasoning. Here, we are considering complexity (or wickedness) that eludes digital

modeling too, which can only address systems with some internal consistency. Byrne [25] criticizes trends of computational (specifically agent-based) modeling because, while the models incorporate some of the randomness of real-world systems and demonstrate features of interest (e.g., how segregation emerges when even a small preference for others like themselves amongst individuals leads to dramatic inequality at city level), these tools are prone to the determination that comes from employing even a complex single model. So, they can fail to acknowledge incommensurability; instead including only elements that can be modeled consistently. On the whole, computational models are not geared to the intangible (yet real) aspects of social systems (i.e., people's ontologies, values and preferences). The process of modeling introduces its own epistemic structures, with the result that other systems of knowing (such as humanistic reasoning in interaction design, e.g. [9]) cannot be incorporated.

Accepting this criticism of the direction that applied systems theory has taken, we value some of the theoretical work itself, such as the concept of *emergence* [40,73], the appearance of effects that cannot be anticipated or secured from a less systemic approach. And another strand of complexity research works more directly with social contexts to circumvent some of the limitations of modeling, which we turn to now.

5.1 Systemic Action Research (SAR)

Systemic action research (SAR) methodology is an attempt to capture complexity in a context-driven, participative way. James et al [69:23] argue that when trying to make changes to a system with large numbers of variables that interact with each other in ways that are hard to disaggregate, SAR creates a 'holding environment' in which to bring together and focus multiple perspectives on the issue. This method typically brings participants with a plurality of voices from diverse perspectives across the social system into a facilitated process of mapping the actors, issues, and conceptual linkages relevant to a research topic [21,22] to gain an understanding of the order of the system. It is a response to the intuition that social knowledge cannot be known in the same ways as scientific knowledge portends to be [43], that it is contingent, partial, and embedded in a complex systemic context [46,92].

Further, SAR assumes that actions taken locally will ripple through the system. How these consequences of actions ripple through the system can reveal much about the basic functioning of the system, and it may reveal opportunities for local action to effect systemic change. Adding awareness of complexity allows us to think about how different tentative, partial and local solutions and the actions associated with them start to impact the wider system and raises questions about how to notice and respond to distributed and subtle change.

5.2 The Principles of Systemic Action Research

SAR's research design includes several principles [20:85], which we share here as they speak to our search for wicked solutions:

- an emergent research design;
- an exploratory inquiry phase;
- multiple inquiry streams operating at different levels;
- a structure for connecting organic inquiry to formal decision making;
- a process for identifying cross-cutting links across inquiry streams;
- a commitment to open boundary inquiry;

- the active development of distributed leadership.

These methodological characteristics work to resist closure. Assessing complexity requires a dialogue between diverse framings from a diversity of perspectives [116]. SAR is structured to deal with complexity, while resembling Research Through Design (e.g. [35,144,145]) in that it makes change, evaluates it and iterates so as to understand and modify the situation. In its use of participatory processes, it is co-designing change, enacted through co-designing the conditions for change to take place.

6 WICKED SOLUTIONS: BEYOND TRADE-OFFS

We now have the theoretical basis in place to look again at unfinishedness. The SDGs framing offers encouragement to think systemically about the interactions in a planetary system, which requires looking beyond trade-offs [98]. *Partnership for the Goals* aspirationally poses the challenge of how and with whom. It intimates that achieving meaningful change is to give up trying for compromises that resolve tensions and seek to meet the objectives of all stakeholders. We have offered an alternative to compromise and disassembling problems, *a la* trade-off thinking (which settles on compromises and ignores complexity), with systems thinking (which tries to hold everything in play). We note that talk of trade-offs has become the ubiquitous response to the SDGs, yet, apart from the immediate shortcomings of compromise, such approaches quickly become meaningless at times of rapid change. This makes designing a high-stakes endeavor; there is no way to avoid conflict and contestation at the existential level. Rejecting trade-off thinking, and including all *Life Below Water* (SDG14) and *Life On Land* (SDG 15) as stakeholders, leads us to wicked solutions.

As we construct our understandings of the challenges posed by current multiple socio-economic and ecological crises--namely that the world is not how it should be--we notice that we face a 'super wicked problem' [94] because it emerges from complexity; because not only is nothing fixed and finite, the problem keeps being reproduced by the functioning of the system as it currently operates. For instance, addressing poverty without addressing (post)colonial patterns and capitalist processes will yield a very temporary and partial respite. Recognizing the emergent nature of wicked problems gives the insight that any particular changes we might make that are not systemic in nature will be undermined and corrected by the "normal" functioning of the system. This is a critical statement about the nature of making social and environmental justice possible, rather than judging what it should entail. It changes how we can go about change-making.

Hence, a *wicked solution* is not a superficial turn of phrase, i.e. simply a solution to a wicked problem. The point is that the solution remains problematic. It remains wicked in the same way the problem has been – emergent, systemic, contingent, partial yet holistic, local but with global ramifications; unpredictable; a dynamic configuration without equilibrium. If such a solution is to effect change, it has to be set loose to take a life of its own and its impact will be emergent from the system.

The different perspectives, framings, and knowledges about such wicked solutions, because they themselves constitute a complex system, will show the same tendencies. They are likely to be incommensurable, and yet they must persist alongside each other in unstable tension--precluding an ultimate, authoritative understanding or solution, but constituting a tentative and partial one, which, like the wicked problem, will not be fixed or finite. It follows then, that if a research/design process can hold onto such a construction so that it becomes part of the structures and dynamics of the system--that is, to the point where a "solution" emerges from the functioning of the (altered/adjusted) system itself--then it may have reached a

better set of relations. Then we can aspire to a world system functioning “as it should” (however we define that) rather than having our best efforts countered by the world functioning “as it does”. This new dynamical state is not to be confused with a fixed end point--it is simply a new structural configuration; but one that is unlikely simply to be washed away by the functioning of the system. It is a *wicked solution* because it eludes finality and universality, it avoids reconciliation, and it exists outside the control of any individual actors or stakeholders with their particular interests and knowledges.

Thus, a wicked solution is wicked because it may not be a solution at all. It is part of a bigger exercise of making change that is ongoing, requiring evolving policy and open experimentation. It speaks to *staying with the trouble* [60] and brings together different knowledge traditions to support this position. Solutions, as we understand them, are ever deferred, both in meaning and outcome. A wicked solution can address the implication of globalizing and totalizing the world’s goals in the system of the SDGs while respecting situated knowledge: it is both globally open and locally meaningful. Like *Partnership for the Goals*, achieving wicked solutions is an aspirational meta-goal.

7 IMPLICATIONS

It may seem that HCI and interaction design has little to offer in this context. It may seem that this matter is essentially of theoretical interest: neither urgent nor useful. However, the implications, if we are to make lasting change, are that we need to embrace less certainty in the shorter-term and design accordingly to support the research initiatives that are interrogating and renewing our world systems. Interactive systems can be designed to support research endeavors that stay more open and treat the intersections between knowledges as just as important as disciplinary knowledges of old. It is difficult to treat social, economic and ecological matters in an interlinked fashion, but, we have argued, important to do so, recognizing the urgency and magnitude of the changes needed. These are issues of survival and renewal. New configurations of tools can help manage research collaborations to be productive in this context.

This is particularly true since attending to dynamics requires more process knowledge than most domain specialists have at present. Cairns et al [26] found the more aware of interdisciplinary challenges the research teams became, the more likely they were to be patient, attempt to understand each other and tolerate ambiguity. Thus, there are actually three distinct components that contribute to where we derive our insights–

1. we need domain knowledge;
2. we need knowledge about how domains intersect or undermine each other; and
3. we need the meta-knowledge that multiple incommensurate knowledges exist so that we can be mindful of them in working with the two other knowledges.

Like this account, a guide to different ways of knowing (and the theory that supports it) is needed. We now turn to the implications of this in design terms.

7.1 Working with “Unfinishedness”

With the urgent need to change our lifestyles and energy patterns, what is known - that knowledge is political, wicked and unstable - is now a prominent aspect of doing research projects in the context of the SDGs, implicitly enshrined in national/international policy and related funding, just as sustainable Development is now a major criterion for devising policy. Drawing on these observations, we can identify several issues that point a path to wicked solutions and a different process for research design:

- Projects anticipating predictable or linear change will become increasingly irrelevant in an unstable world.
- Design theorists are already pointing to the need for deferred meaning and outputs addressing wickedness.
- The deferral of meaning in addressing planetary issues presents a design-in-use case [108], where different projects' outputs find their value in association with a great many others that link to, or challenge, the results.
- Interventions as perturbations are catalysts (stimulating change), rather than prototypes (modeling change), as action research starts to merge with Research Through Design [39], to understand intra-actions [8] as much as to change states.
- Yet, changed states will emerge from interventions, implying some responsibility for anticipatory work to consider and observe change elsewhere in the system.
- However, repetition may not yield similar results - the original system will have moved on at $time_2$ to $system_2$, potentially also affected by perturbations from other parts of the system or from outside it.
- Nonetheless, monitoring to see the impact of different experiments is critical to understanding how interventions might be applied further, halted or changed.
- Teams need domain expertise and, *in addition*, expertise in design, systems and managing uncertainty.

7.2 Tools for Changing Times

The list above links theory to the practical implications of planning for unpredictable dynamics. We do not know what perturbations will be beneficial. This means all design and Development becomes research (and vice versa). Research projects are small-scale pilots that do not directly lead to scalable change. One classic response is to propose scaled-up versions of what works, but we take issue with that approach, since:

1) We will never fully know what works;
2) What works is contested;
3) While a big coordinated intervention might have a bigger impact than smaller micro-level interventions, it is important to question power and consider who has the authority to impose such an intervention on the system.

If, instead of trying to scale, we consider work on the irreducibility of relations gaining circulation in eco-feminism, posthumanism, Indigenous Knowledges, biology and other domains, part caught in Margulis' [89] notion of Holobionts (assemblages of species in ecological units) and Haraway's [60] tentacular thinking (webs of everything), we can take a more modest, care-full approach to making change.

We will not dwell on how different the fragmented, contradictory nature of SDG ambitions is from the poetry of deep relationality in more systemic philosophies, but point to the literatures that inform our thinking here. In designing our tools to be systemic, we can keep both the 17 SDGs and *staying with the trouble* [60] in mind, as well as crises of land misuse, fires and floods, pandemics, and dependence on fossil fuels. This is in itself to live with contradiction. Yet, for most designers and specialists working for sustainable Development (or renewal/restoration), the functional nature of design is its value. It is a major form of human agency; it holds the possibility of a new era of Development, despite/with accelerating change.

Irwin [68], reflecting on designing for *transition*, suggests many tools and methodologies are needed; no one process can be effective. We have taken up this point to ask foundational questions about managing uncertainty, as a practical correlate to new thinking on its impact [118]. We now consider tools in that light.

This is not to close down or instrumentalize the work of thinking through tensions and iteratively and creatively framing resultant collaborative work; it is also not to define what is to be sustained. Rather, it is to discuss the support that such processes could use, welcoming the lesson in the SDGs about systems thinking and responding the call to 'grapple with the full multi-scalar complexity of "wicked" sustainability problems' [123], without seeing the SDGs as the final word in global policy.

8 ASSEMBLING THREE TYPES OF TOOL

In this section, we propose three types of tool, which, taken together, might support knowledge work in/for changing times and how we form new approaches and respond to policy work to meet global ambitions. We do not try to pin down the characteristics of actual tools but consider what qualities might support the need for "unfinishedness" in the context of socio-ecological renewal. We do so by reflecting on the materials we have shared, taking us through design theory and complexity methodologies to offer some management tools for wicked solutions in an age of global challenges (as caught, but not exclusively, in the SDGs). First, we propose a way of thinking about the design of these tools that sets them apart from current initiatives.

8.1 Some Play in the System

Many years ago, it was pointed out that one can choose to design a flexible medium or a fixed mechanism [13] and that the former offered appropriation and reuse. In the spirit of infrastructuring [29,105], or 'the work of creating socio-technical resources that intentionally enable adoption and appropriation beyond the initial scope of the design' [29:247], our priority is to enable responsiveness, noting that the systems we use will need to change, in line with external shifts and with learning as it emerges from different sources. Designing technical systems may traditionally mean building new institutions by embedding rules and setting up new relations that are intended to persist. Here, we propose to model tools more on 'play states' than new institutions, staying nimble and reinventing themselves in response to the environment, while protecting the information in their care. Ideally, too, tools to support knowledge-sharing also reinforce understandings of knowledge diversity. They might give insight into design and complexity theory in practical ways to support research design. This would be a logical and practical progression from the arguments we have been making about the way that knowledge needs to be approached and how the SDGs foreground this.

8.2 Spatial Tools

A first type of tool situates the research. How do experts orienting to a dynamic system know what is happening elsewhere and how these activities connect and impact on each other? We have shown that wicked solutions are held in suspension by domain intersections, by changes to the context and by the nature of perturbations. This knowledge will be prone to the concerns, noted above, of failures of communication and ontological mismatches. Nonetheless, the evolving planetary system is a major actor in framing Development, which the SDGs highlight, and everything could be part of an investigation. We need tools to help us know where to impact, where to look for impacts made and how to interpret them.

Databases support areas of research and already include data about who is doing what at a global level, linking teams, storing basic insight about what they are doing, how and what they are finding. Design knowledge has been applied (e.g. [72]), so, this is not to suggest this is a new area of technical work, but to draw attention to how such systems could be used more and differently for coming challenges. It is to stay

alive to participatory processes of co-designing the conditions for change to take place. A global system that connects domain systems across languages and ways of thinking is a mind-boggling idea and brings with it all the problems we have been discussing, but it is the logical conclusion.

Practically, we know that, while work undertaken in each context will be unique, it will contain elements that repeat across locations and scales. We know that many human ontologies (i.e. ways of knowing) cannot be aligned, so how knowledge is understood, experienced and passed on in different ways will reveal important knowledge about worlds of operation in addition to scientific mapping. In whatever way specialists choose to focus on an issue, the design specification of the system must allow for that chosen frame of reference so that we begin to address knowledge hierarchies and the politics of old Development paradigms. So, one challenge will be to incorporate whole worlds of data and another will be to keep the original ontological and epistemological terms of those data intact. We can stay mindful that there are more ecological ways of knowing and that any single system tends to lose context and eliminate plurality [137]. This is also committing to “unfinishedness”. This is important if we are to reverse the colonial appropriation of knowledge and, with it, the dismissal of that which does not fit the Global North dominant paradigm.

At the same time, mapping can draw boundaries round individual projects and evolving problem frames, ordering the social processes of tentatively generating solutions, with no assumption that all these realities and versions of reality fit neatly together. In doing this, it can demonstrate where cut-offs have occurred and what knowledge and association is being left at the edge or could be included with minimal rethinking. Keeping maps of connections open helps situate the project as relations change and impacts are traced. As much a symbolic reminder as functional tool, it represents the instability of what is being mapped. It would be possible to make such porosity into a design aesthetic, as well incorporating it as a fact of comparative epistemology. Ideally, experts from one ‘world’ of knowledge would be able to put themselves in relation to a different way of understanding and see their work and that of others through a different lens. Spatial tools can go beyond mapping to be tools of perspective.

8.3 Temporal Tools

If we are looking at fluid, contingent and partial solutions, temporality comes into play. This has at least two potential design implications. Remaking, retreating, rethinking, reorienting and tweaking are major parts of research design already. But often the path of a decision is obscured as soon as an avenue is rejected. As noted above, this forecloses options. Cairns et al [26] deliberately followed these decision paths in the context of the SDGs and retrospectively asked teams about their choices, but there cannot always be a researcher to research team decision-making. Action research stresses good note-keeping so that assumptions can be tested [107]. Work in design on reflection and annotation speak to this too [28,52]. Tools that capture a timeline of choice-points and decisions, the flow of exchanges between disciplines (and even the power issues of which type of domain has ascendancy) can act like a time-machine, so that decisions can be reversed with greater insight into how they were achieved and why. Supporting this dimension leads to an emphasis on the steps in the process so that, as well as monitoring change in the system, we can relate it to choice points, wider impacts and the effect of rapidly changing conditions. A slippery timeline might also work, politically, to balance ways of knowing and integrate them without compromising worldviews. It might be possible to go back and ask: what if a different methodology or way of knowing had led our questioning? It

could allow teams to address evolutions in conditions and/or in policy, while staying alive to the political dimensions of knowledge-making.

If a timeline can function as a way of laying out process, it might also yield more anticipatory support by begging the question of consequences and potential futures. It might be a means to run and rerun the shape of a project, anticipating the impact of different domain expertise and interventions. It is not only a chance to reverse priorities, but to change priorities based on a changing context.

The second benefit to come from considering temporality is in the 'design after design' [108] of tools. Designers have tended to think of a particular lifespan in regard to designs, assuming an upgrade at a point within our control. But, if we know that our tools will need to be refashioned for unknown future purposes, this reframes the notion of lifespan. Rather than creating a thing that will last for a time, we can create a way of creating, so that when the function or aspiration changes, we are not left with a tool designed for another purpose. Instead, we have a meta-tool for generating new tools appropriate to the new conditions.

8.4 Tools of Meaning

If, last, we consider what conceptual support might be possible, then we are looking at how to suspend solutions in two senses: first, our tools can help set aside the tendency to believe that clear solutions can be found to problems of this level of complexity; second, our tools can hold multiple partial solutions together, allowing them to function as a coherent response to existential challenges while remaining incommensurable, potentially contradictory and open. This mirrors the uniting/fragmenting contradictions of the SDGs. Meanwhile, Haraway [59:160] tells us that 'Mathematically, visually, and narratively, it matters …which systems systematize systems'. Our suggestion is to make systems that keep open the systems they create, as well as to be systemic in approach. Much of this is about how data is interpreted and meaning is made in different knowledge worlds. How then do we capture these nuances in a meaningful form and help notions of wickedness spread?

One of the most powerful tools of this kind at present is the interdisciplinary hub. For instance, [where an author works] has a sustainability program open to all university faculty. Design researchers mix with ecologists, critical theorists, psychologists and Development experts. Learning about other epistemological positions takes place, solutions are challenged and relations form that help transcend frustrations. This speaks to Cairns et al.'s insights [26] that friendship and aligning of values preceded the SDG projects they observed. Of course, working relations and meeting places were impacted by the Covid pandemic and in 2020-21 we are still processing what this has meant for collective knowledge-making and sustained engagement across disciplines and projects. We are challenged to ask what virtual and face-to-face mix is optimal for growing such encounters from the local context to the multi-local world of different actors? The interaction design of our communication systems can map the micro-interactions of team, community and research institution to the bigger issues of interdependencies and relational, pluriversal understandings of issues in such ways that there are immediate practical and longer-term conceptual connections to be made.

Here we might observe that a focus solely on the making of *knowledge* can blind us to the more profound motivations of the makers. Cairns et al draw attention to the shared values that made it possible for the researchers they observed to span types of knowing and come together to combine strengths, while having patience with and learning from their differences [24]. Researchers spoke of 'similar interests and a similar ethos. We're all interested in these big environmental problems, particularly …minimising harm to the

environment' [24]. Cairns et al talk of a shared normative framework underpinning research, which was felt to transcend disciplinary divides and kept attention focused on the broader 'why' of coming together. We might build on these observations with those of Frankl [48:2.317], that people make meaning through connections with others, co-creating their contributions to the world and choosing how to respond (e.g. with courage) to existential crisis. We might be reminded of Arendt's distinction between work and labor – the former producing enduring artefacts with meaning to the maker; the latter merely materials for immediate consumption [6]. Tools for meaning should help people beyond collaborating practically to produce knowledge – or even to create wicked solutions. They should help people feel that their shared work to produce knowledge and wicked solutions is meaningful and relevant. Obviously, being able to situate one's work, as spatial and temporal tools allow, is part of making sense of one's work, but there are relational elements that cannot only be articulated as factors of time or space, but manifest as interpersonal or self-reflexive.

We will need skills for communicating (and being self-aware of) our own epistemological positions and how they complement or even sit uncomfortably alongside those of our colleagues. As Strathern says 'self-consciousness about "knowledge" is a tool for knowledge making' (p64). We need tools that facilitate the kinds of interactions that share knowledge and respect ways of knowing, noting that we cannot know exactly what interactions or activities we will need, and so cannot know ahead precisely the spaces needed to facilitate those things. But, clearly, we need tools capable of promoting a collective understanding and collective action bigger than ourselves. The predictions are for greater political isolationism, competition for resources and movements of people that make knowledge-making difficult. The SDGs run in a counter-direction, a hopeful achievement of global governance at a time when our world requires it but our politicians and their policies are not so in tune. Our tools as scientists should stand in opposition to fragmenting, while remaining alive to the contexts and cultures from which thoughts and actions emerge. They should be designed to challenge loss of coherence, even as they acknowledge there is no one truth in the first place. (It is interesting to see how Latour has gone from dis-assembler of scientific absolutism to advocate for science, under the stress of fundamentalist and disinformational attacks [76,83].) We need to be less vulnerable to civil upheaval and other forces [74]. And our knowledge tools (and access to them) need to stay egalitarian, just as knowledge should [100]. While these last requirements are overtly political, they merely go to show again that it is impossible to divide the realms of the technical and the political [34,75] in responding to climate change. That is part of the message of *Partnership for the Goals* (SDG17).

8.5 Bringing it Together

These types of tool together help to construct an entry point into the global system reflected in the SDGs, in real time, over time, in multiple places and contexts at once. As is obvious, the notes here are not a specification, but rather a statement that our tools can promote useful outcomes, while what they need to do is only partially clear. These are characteristics that, like the research, carry their own contradictions and even paradoxes, yet they are useful as thought-twisters despite the real possibility they may defy simple manufacture. Above all, they present the need to manage flexibility in their design, so that they stimulate creativity and innovation in their own use and adaptations, to seek out and nurture their own innovative uses and recombinations. This is to embrace uncertainty in its full uncomfortable sense and respond to the challenge in global policy and, more importantly, in global crisis.

We started this paper by saying that all issues of concern are now notionally held within this super-charged global design challenge and that we, as HCI researchers and interaction designers, are implicated. Tool-making is, of course, one of the ways and we have described how this might be approached, pointing out that much of the scientific novelty invited by the SDGs is in thinking what happens when knowledges are connected up. But there is another level of implication. We have explained the theoretical aspects of this paper in some detail, as support for reflective thinking on disciplinary dynamics, as well as to make an argument. We too have disciplinary dynamics to reflect on. We write in pursuit of system change, aligned with SHCI (e.g. [75,123]) and LIMITS (e.g. [96]), believing this change begins at home (e.g. [87]) and asking HCI to raise its game. We cannot afford a reading of the future that is uncomplicated or a sense that interaction design can only respond to climate change with reuse and repair. We hope this paper, in developing existential themes in the context of rapid change and incorporating them into design, will help give the lie to such positions alongside other works on the more-than-human. This is not an argument for uncritical use of carbon for computing. But, if the ambition of SDGs makes one thing clear, it is that, while we have the use of joined-up computing, we should work toward joined-up knowledge that is wicked in all the best ways.

9 CONCLUSION

> Life is not divisible into the departments of a university. … Emancipate the ideas and they will burst forth into co-evolutionary bloom in a nearly unreadable knot of spiraling influences. They will leak into each other. [11]

Does this paper and its recommendations suggest that we never talk further about problems and solutions? Far from it. What we discuss is responding to the SDG framing of Development work, and this does not dismiss existing practice but complements it. We have suggested it is important to understand design, complexity and how the SDGs configure Development in order to think through the implications of this framing in the context of rapid change. The re-representation offers an unprecedented opportunity to consider how to support the design of research and Development with sensitive tools that go beyond mere function to help explore ontologies of the future as we rethink our world.

We do not offer guidance in the form of design specifications. For those who like closure, our contribution may seem too indeterminate. We suggest that this is, for better or worse, in the spirit of the changes we address and that a long history of work already speaks to a desire for closure, which is, in part, what we are considering with this paper.

Design is under fire as an unsustainable force that promotes consumerism, contributing to wasteful energy use and delivering unnecessary upgrades. Such work, with its implicit link to production of digital artefacts, has a large carbon footprint. Working to support renewal and promote a fair, fulfilling world for all life is a way to ensure that resources are put to good use. Promoting “unfinishedness” may seem a curious starting point, but as greater uncertainty impacts the world, the ability to respond to uncertainty and remake our tools in its image may be our greatest asset.

10 ACKNOWLEDGMENTS

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