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Shifting the maturity needle of ICT for Sustainability

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Abstract

The ubiquity of ICT means the potential of ICT4S covers a broad range of sustainability topics and application domains. However, ICT4S research can be ill positioned with regard to the complexity of transforming society in such a way that people and environmental ecologies can coexist in a sustainable system. The danger is that ICT4S becomes partitioned into a small subset of sustainability and using a limited set of the levers at our disposal. Grounded in the Mann-Bates maturity scale for sustainability this paper performs an analysis of the ICT4S conference corpus to measure how mature the research is in our field with regard to sustainability. Based on this analysis we identify areas in which the ICT4S community can begin to shift the maturity of research in order to promote sustainable futures. By applying the Transformation Mindset our article demonstrates through a series of illustrative how ICT4S can apply this mindset to shift ICT4S research towards more sustainable trajectories. This is an essential first step in taking stock, highlighting shortcomings and identifying opportunities in ICT for sustainability.

1 Introduction

This paper presents a critique of the current state of Information and Communication Technologies for Sustainability (ICT4S) research in terms of how it supports transformations towards sustainable trajectories. In this paper, we lay out the Mann-Bates maturity scale [1] and use it to present the results of an analysis of the ICT4S corpus. Based on our results we establish the need for a step change in the design and impact of ICT4S research and practice - a “shifting the needle”. The Transformation Mindset [2] is used to ground the second corpus analysis of ICT4S. We demonstrate how applying

Transformation mindset in ICT4S can help shift the maturity of computing research towards sustainable futures.

The ICT4S conference series aims to bring together "leading researchers in ICT for Sustainability with government and industry representatives, including decision-makers with an interest in using ICT for sustainability, researchers focusing on ICT effects on sustainability and developers of sustainable ICT systems or applications"[1]. The themes of the ICT4S conference have looked to address the challenges of making sustainable futures real (2013), ICT and transformational change (2014), building a knowledge base for environmental action and sustainability (2015), being smart and sustainable (2016) and thriving communities (2018). ICT and computing research in ICT4S has focused on topics that can be broadly categorised as digital innovation for sustainability, smarter cities and infrastructures, taxonomies and frameworks for sustainability, sustainability in education, increasing the energy efficiency of digital systems, resource consumption and life cycle analysis, and practices and systems thinking.

Examples of research that considers smarter cities and energy infrastructures includes understanding how to manage smart cities [3], decision making in organisations [4] and the challenges of living in situations where energy supply and infrastructure is not guaranteed [5]. Work to develop new taxonomies and frameworks have considered a framework for tackling environmental complexity [6] how to develop sustainable computing and catalyse change at scale, and a framework for assessing future scenarios [7]. Education and sustainability has been discussed in terms of how to get students in higher education more involved in sustainability [8] and the links between sustainability and ethics [9].

Research considering how to develop more efficient digital systems has looked at evaluating the energy efficiency of software [10], modelling the environmental impacts of ICT [11], and the energy and carbon footprint of data intense digital services [12]. A variety of work on resource consumption has included smart metering (e.g. [13]) and life cycle analysis of ICT (e.g. [14]). More holistic views grounded in complex socio-digital systems have helped ICT4S consider social practices in smart cities [15], how digital growth in practices may be unsustainable [16] and the importance of a systems thinking perspective in ICT [17].

This all sounds wonderful. So what is the problem? The authors were struck with a nagging feeling that ICT4S might not be doing enough - that we might be fiddling while Rome burned. We aimed to identify if current research in ICT4S was helping to deliver transformative change towards sustainability. If not, where there were opportunities for increasing its contribution? We first set out to explore this by analyzing a corpus against a sustainability maturity metric. This same metric - the Mann-Bates maturity scale – can help researchers and practitioners to develop their approach towards more transformative outcomes.

Ours is a first essential step in taking stock of the current ICT4S discourse, highlighting shortcomings and identifying opportunities. As such, our primary contribution is an analysis of the ICT4S corpus that provides a framework that can start a rigorous discussion about the maturity and transformative nature of ICT4S research.

2 Corpus Analysis: Maturity

2.1. Method

Based on the Mann-Bates maturity scale [1] we have performed a corpus analysis of the ICT4S literature. In total 153 papers were reviewed. Each paper was assigned a category based on the Mann-

[1] http://ict4s.org (accessed, Nov 2017)

Bates maturity scale (after Willard [18]). This was done by two authors independently assessing the corpus and discussing the conflicting cases to come to agreement. The descriptions for the scale describe the apparent mindset and motivations of the authors of each paper. As only a few papers describe these in detail, we had to infer them from the scope, method and language of the paper. If in doubt we were generous but as this is an external assessment, representing internal motivations, we do not discuss the scores for the individual papers[2]. As the interest here is a summary view of the whole of the corpus, we believe this is appropriate for this paper. A five-point scale was used with 0.5 increments (that is, where something straddled two categories the midpoint was used). Although the Mann-Bates Scale was intended for considering Human Computer Interaction for Sustainability only very trivial changes were required to expand this to all of the research under consideration (i.e. removing the "HCI" in "HCI research").

The categories are described as follows:

Avoidance (Stage 1): The researcher feels no obligation beyond publication. Research focuses on development of products without regard to wider implications. Ignores sustainability and ethics and/or actively argues that it doesn't apply to this research.

Compliance (Stage 2): The researcher manages their ethical responsibilities as compliance. The researchers are aware of some implications and perhaps include a small section in the discussion that acknowledges a single sustainability factor, but wasn't incorporated into the research question, methods or outcomes

Use (Stage 3): Research is about products that deliver incremental, continuous improvements in eco-efficiency. For example, sustainability as an opportunity to explore aspects of computing, encouraging behaviour change or different ways to communicate. Little attempt to question whether the activity being made efficient is sustainable in wider terms, nor alternative approaches. If sustainability is defined, then it is the three pillars or "environmental sustainability".

Reason (Stage 4): Research on sustainability, using computing as the lever. It references complex sustainability themes. It is value driven. It adopts holistic sustainability, integrating all aspects through process based approach. In this stage, different models become apparent - understanding products as a means to deliver a service to a customer. Researchers are more likely to talk about empowerment, democracy, participation and social systems than they are interventions for behaviour change.

Note that Willard [18] (upon which [1] is based) describes the shift from Stage 3 to Stage 4 as a "transformation" whereas the early steps are "transitions". Thus moving from "use" to "reason" requires internalising sustainability notions in profound ways, both personally and organisationally.

Passion (Stage 5): The transformation to "Passion" is where proactive socio-ecological transformation becomes the premise of the research. Driven by a passionate, values-based commitment to improving the wellbeing of society, and the environment, the research helps build a better world because it is the right thing to do.

"Reason" researchers do the right things so that they are successful researchers. "Passion" researchers are successful researchers so that they can continue to do the right things where the right things are to drive a positive socio-ecological transformation

[2] The corpus dataset is available here: https://wordpress.com/post/computingforsustainability.com/3384

2.2. ICT4S Sustainable Maturity Results

Figure 1 shows the distribution of the entire ICT4S conference corpus analysis on the Mann-Bates Sustainable Maturity Scale. Our results demonstrate how the large majority of ICT4S focuses on either compliance or use.

In all years the bulk of papers are at the lower end of the maturity scale and this is reflected in the total for all years. If this was represented differently– as an analogue pressure gauge – the needle would be hovering in the "compliance" zone. We find this worrying. What is more worrying is when we remember that ICT4S is perhaps the premier conference for people concerned with sustainability using computing as the mechanism for change. A corpus of the rest of computing research would produce a far worse result.

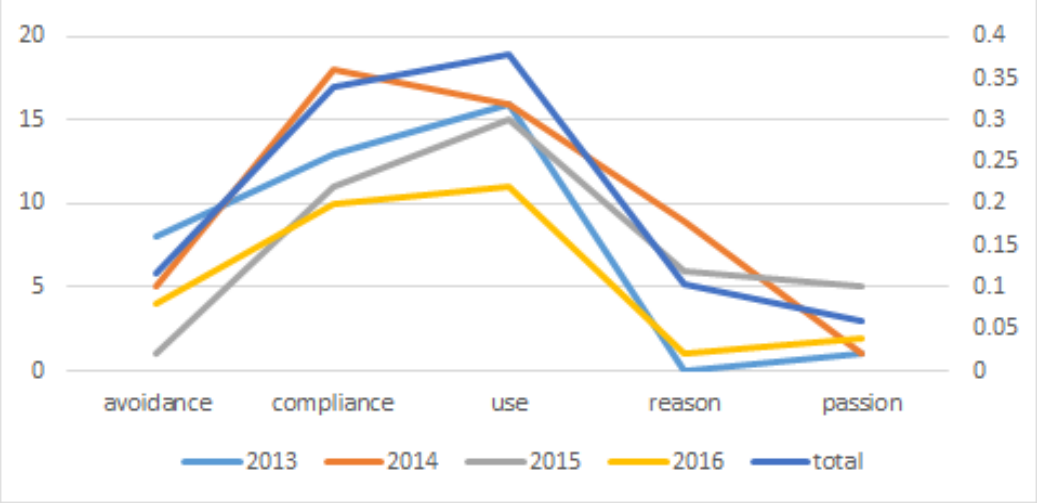

Figure 1: ICT4S conference corpus analysis based on the Mann-Bates Sustainable HCI Maturity Scale. Absolute numbers of papers in each year on left-hand vertical axis, the proportion for the total corpus on the right-hand vertical axis.

2.3. Shifting the Needle

In the remainder of this paper we consider how we might shift this hypothetical needle. There are two aspects of shifting the needle. The first is identifying and articulating how ICT4S research could be improved. The second is considering how to accomplish this - where should we distribute our efforts? Perhaps in providing resources in undergraduate education, or in inspiring a more holistic perspective in the design stages of PhD research, and so on. In the remainder of this paper, however, we focus on the former – the nature of the research itself - what could we add (or take away from) ICT4S research to make it better? We do this using a Transformation Mindset.

3 Transformation mindset

Mann *et al*. developed a Transformation Mindset [2] as a means to guide practitioners in becoming a sustainable practitioner as part of their professional framework of practice (p13) [19]. Mann *et al.*

defined the “Transformation Mindset as a way of thinking that leads to transformational acts resulting in socioecological restoration” [2]. This transformational focus came from Leach *et al.* who argued that “what is now needed is nothing short of major transformation – not only in our policies and technologies, but in our modes of innovation themselves – to enable us to navigate turbulence and meet Sustainable Development Goals” [20].

While some avoid a problem formulation, preferring a positive framing of opportunities (e.g. a baby is not a problem but something precious to be nurtured [21]), the challenge posed by unsustainability can be usefully considered as a “wicked problem” [22]. This means it involves complexity, uncertainty, multiple stakeholders and perspectives, competing values, lack of end points and ambiguous terminology. It means dealing with a mess that is different from the problems for which our current tools and disciplines were designed. As individuals and disciplines we are ill-equipped to cope with the messy complexity we now face. Adomssent et al. saw sustainable development from a holistic perspective; it can be understood simultaneously as a concept, a goal and as a process or strategy [23]. The concept speaks to the reconciliation of social justice, ecological integrity, and the wellbeing of all living systems on the planet. The goal is to create an ecologically and socially just world within the means of nature without compromising future generations.

We posit that a sustainability-based transformation mindset may be beneficial on the following premise: Sustainability is the process or strategy of transformation toward a sustainable future. The transformation mindset provides a structure for that and therefore for provides guidance for disciplines such as computing.

1. **Socioecological restoration** over economic justification
2. **Transformative system change** over small steps to keep business as usual
3. **Holistic perspectives** over narrow focus
4. **Equity and diversity** over homogeneity
5. **Respectful, collaborative responsibility** over selfish othering
6. **Action in the face of fear** over paralysis or wilful ignorance
7. **Values change** over behaviour modification
8. **Empowering engagement** over imposed solutions
9. **Living positive futures** over bleak predictions
10. **Humility and desire to learn** over fixed knowledge sets.

Figure 2: Transformation Mindset [2]

Mann *et al.* [2] describe the sustainability-based transformation mindset (Figure 2) as follows:

The mindset can be considered with a device recognisable to those familiar with software engineering’s Agile Manifesto – a list of values and attributes arranged so that each is defined in part by an opposing value [24]. The agile manifesto structure finishes with "that is, while we value the items on the right, we value those on the left more". These things on the right then are not inherently wrong – we could find people attempting sustainability doing those things, but we argue that the things on the left are better. Hence, for example in The Transformation Mindset, Item 7, “values change over behaviour modification” can be read as ’we value things that modify behaviours, but a focus on values change (and hence behaviour) is stronger’. Most of these items

also carry more than one message. Item 7, for example again, also speaks to the problem of change by appealing to inappropriate values such as promoting "green" actions because it is cheaper rather than because it is the right thing to do (otherwise, what happens when green turns out to be more expensive?).

While each item can be considered separately, they are not exclusive and tensions between the items provide much of the challenge. The elements of the Transformation Mindset are further explored in relation to ICT4S in the sections below.

The Transformation Mindset can be used to consider different development initiatives. Figure 3 gives a graphical version of the Transformation Mindset in which the elements of the mindset can be positioned on the 10 axes. Note that in keeping with a mindset rather than a detailed set of metrics, the positioning on each axis is subjective. For each, the inner ring describes actions that usually align with a weak sustainability, and the outer ring a transformational approach. The centre of the image, inside the inner ring, represents actions that could be considered unsustainable, or where that element is not addressed at all by the development. As the arrangement of the axes around the circle is arbitrary (clockwise from the top) no inference can be drawn from particular shapes on the diagram. Further, as this is an holistic mindset - you cannot substitute socioecological transformation by maxing out equity or some other element - it would be inappropriate to compare total "scores" for individual papers.

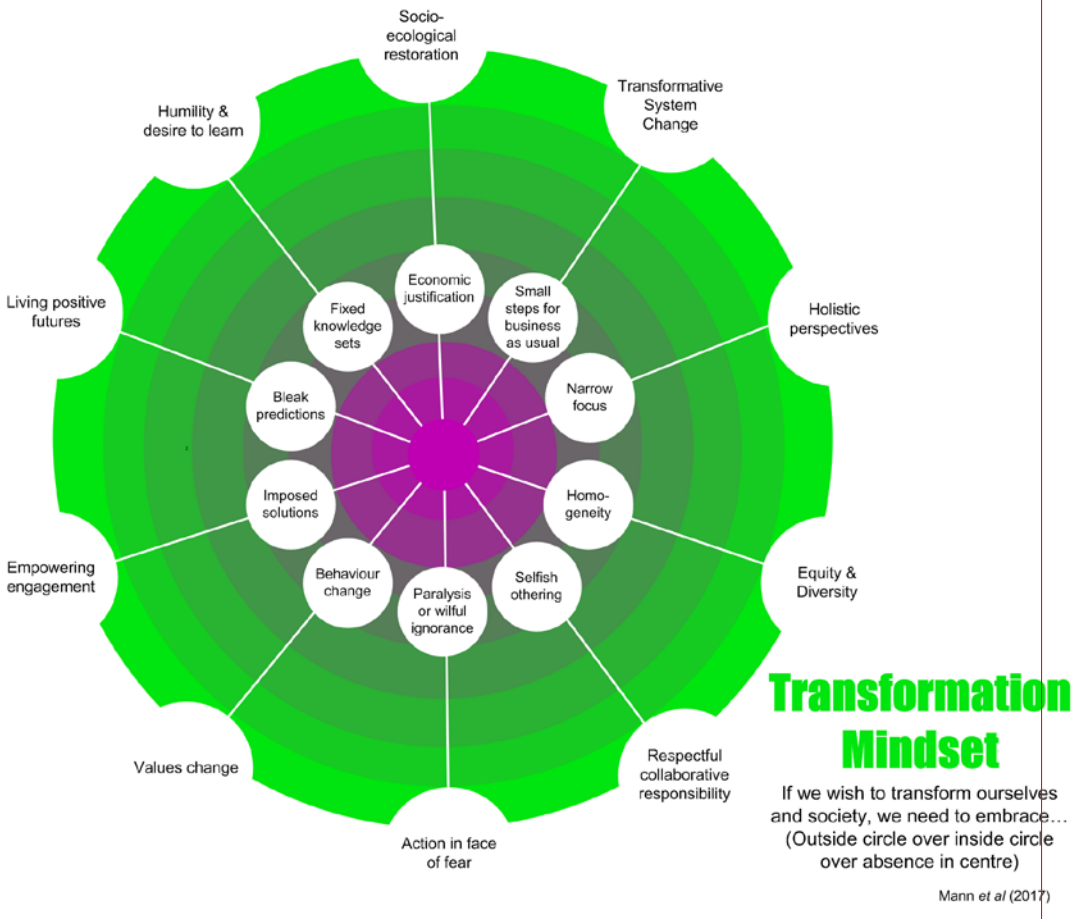

Figure 3: Graphical version of the Transformation Mindset

4 ICT4S Corpus: Transformation Mindset

4.1 Corpus transformation method

The ICT4S corpus was analysed according to the Transformation Mindset using the same procedure as described above for maturity. Each paper was graded against each of the ten components of the Transformation Mindset on a scale of 1 – 10 with ten the highest.

4.2 Corpus transformation results

The overwhelming majority of papers are at best demonstrating a weak sustainability. The mean for the individual elements range from 3.2 (Equity and diversity) to 4.5 (Humility and desire to learn). While a crude measure, it is useful to glance at the distribution of total scores for papers. The most a single paper scored was 78 (/100), with a mean of 38.4, stddev 13.1, the upper quartile only 47. The distribution of all the papers is shown in Figure 4. Mapping the corpus in this fashion provides an alignment with the Mann-Bates analysis. Like the maturity finding, there is much room for improvement.

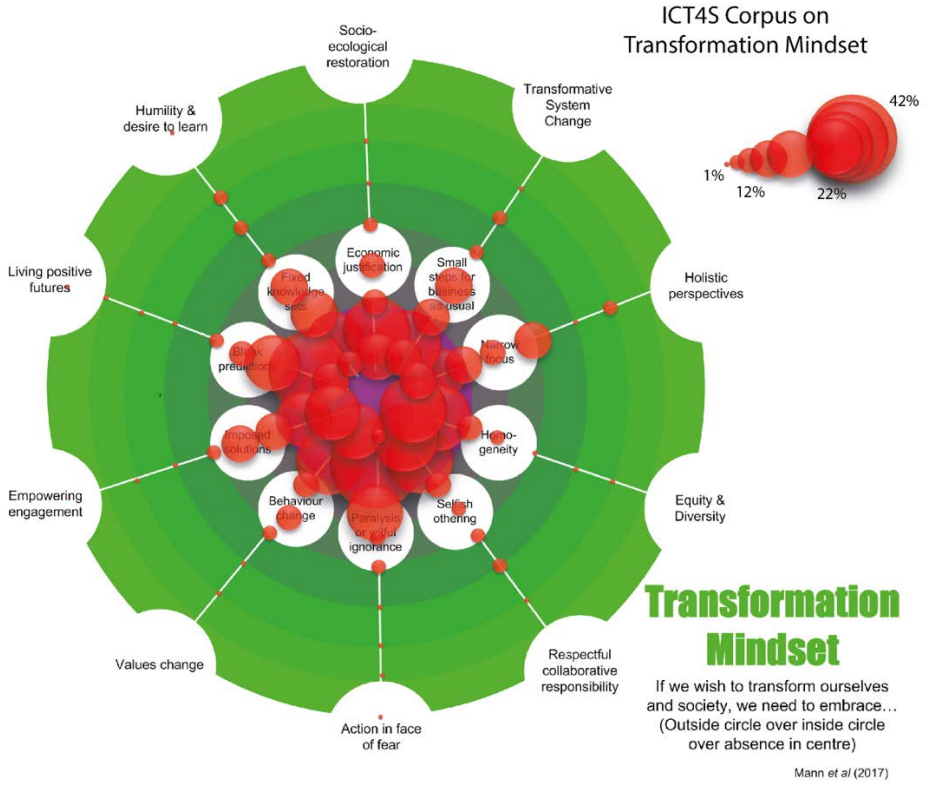

Figure 4: ICT4S Corpus plotted on Transformational Mindset (see Figure 3 for obscured words on inner ring)

5 Transforming ICT4S

The remainder of this paper describes the individual elements of the Transformation Mindset and presents previous research initiatives that address some or all of these elements. Mann [25] applied the transformation mindset to computing education for sustainability and later asked "What will it take for Computing to Save the World?" [26]. In that latter paper, projects were discussed that exhibited different positions on the Transformation Mindset. In the current paper we repeat this exercise, but focusing on examples from ICT4S. The intention is to provide a roadmap, or a pattern of sorts for how ICT4S could shift the needle by including some of these approaches in research design.

1. Socioecological restoration over economic justification

This item makes clear that the point of sustainability is socioecological restoration. Economic development or reasoning is not dismissed but should be seen as a means to achieve benefits in social, cultural and environmental aspects – a vehicle for sustainability, not a goal in itself (this aligns with Daly's Strong Sustainability [27]).

The combined socioecological wording is a deliberate modification of Olsson *et al.*'s "social-ecological" to bring it in line with constructs such as "socioeconomic" [28]. It represents an acknowledgment that humankind and the environment are inseparably intertwined. Sustainability is not just about single factors such as efficiency gains, and the problem is not just about carbon or energy; the systems in question are as much social as they are biophysical. Note, however, that this is not a justification for "social sustainability", or "environmental sustainability" - as previously argued ([29]) separately considering elements of an integrated system is a backwards step.

The restoration element is both an acknowledgment of the current path of degradation and a commitment to repair, not just stabilise or maintain in a degraded state [21]. ICT4S papers that demonstrate aspects of this element include [30][31][32][33]. But these are largely review papers, or descriptions of contexts (e.g. Gui [34]), none really embody this element in practice. Perhaps the closest is an exploration of urban agriculture that takes an integrative view of the creation of "green maps" [32].

Delivering this element is a great opportunity for ICT4S.

2. Transformative system change over small steps to keep business as usual

It is widely argued that making small improvements, while maintaining the status quo, is unlikely to result in required changes for a sustainable future. It is unfortunate, then, that the vast majority of ICT4S papers describe incremental improvements (and almost entirely in one area: energy efficiency).

Transformation is used here to move the focus beyond the comfortable perception that global environmental challenges can be met through marginal lifestyle changes. Small changes are necessary but insufficient – we live at a time when we need urgent and ambitious changes [29][21]. Instead of solely working on small things and hoping that they add up to a change (themselves or with 'spill over'), we need to focus on things that multiply to create positive system change.

While looking for system changes, we need to be careful not to put too much reliance on "miracle cures". The clue is that computing is tool that facilitates and enables social change, rather than a technological saviour. Waiting for technology to deliver efficiency gains through behaviour change, or even not having to change behaviour, is what Krumdieck refers to as a green myth "it's the miracle just around the corner so we can carry on business as usual" [35]. Toyama has a similar concept in his "geek heresy", that we think that throwing technology at problems is going to solve them, but his thesis

is technology exemplifies underlying human forces [36]. If we are continuing to consume, and that's the primary human force, then throwing technology at it is not going to solve that problem.

Espana [37] sees the development of “responsible software” which “goes beyond reducing computing-centric energy use and focuses on achieving technological and corporate strategic objectives by maximizing benefits for society at large” and although this work is perhaps overly techno-solutionist, it does propose fundamental changes, not a more efficient business as usual.

The ways we communicate shape how we perceive the world we inhabit, how we solve problems, who we communicate with and the ideas we share. In short, all the elements of culture that must evolve as we advance toward a sustainable future. Therefore, transforming communication technology offers great potential for transforming global society towards sustainability.

3. Holistic perspectives over narrow focus

This item refers to bigger-picture thinking. This bigger picture applies to time, space, disciplinary boundaries, species boundaries, approaches to inquiry and so on.

The first step to transformative system change is to describe the context in terms of systems -([38][39]) and preferably integrated socioecological systems ([21]), then to look for flows and levers in those systems. This is holistic in every sense. Sustainability requires a systems approach. People need to be aware that their actions have impacts. These impacts may be intended and unintended, across scales: temporal, spatial, social, and have positive and negative effects. People need to understand forms of relationships (hierarchies, partnerships, feedback) and that humans form part of a complex web. Systemic thinking emphasizes patterns, trends and feedback loops.

Sustainability can be described as ethics extended in space and time [19]. This wider ethic calls for solidarity with the entire Earth, ecological sustainability, lifestyles of sufficiency, and a more participatory politics. The underlying force of sustainability as a concept is intergenerational equity but this is largely overlooked – our time spans of concern are almost always far too short.

Much of the ICT4S Corpus can be characterised as the antithesis of this approach. Many papers claim to about sustainability, but then narrow this to climate change, then to energy then to energy efficiency, then a ICT tool to manage efficiency, then a very short term and small scale intervention. This rapid descent down a reductionist slide would be acceptable if it were at least acknowledged, and not be the path followed by the bulk of papers in the ICT4S Corpus.

But there are papers that take a different path. At a meta level, Easterbrook’s argument that we need a rethink from computational thinking to systems thinking [39], while Joshi grounds a discussion using the Fariphone as a motivating example [40].

Shabajee [31], while focusing on adaption to climate change, recognises the complexity of changes in local and national socio-economic and political contexts, and the relationship of these to ecological concepts of resilience, vulnerability and adaptive capacity. Scale is explicitly considered, both spatial and temporal.

Other ICT4S examples of this system change element include:

- Sustainability Begins in the Street: A Story of Transition Town Totnes [34]
- Education and Health in ICT-futures: Scenarios and sustainability impacts of ICT-societies [33]
- Multi-perspective ICT-toolkit supporting inclusive and sustainable mobility planning in rural areas [41]

- Smart Cities MOOC: Teaching citizens how to co-create smart cities [42] - energy, education
- Sustainability Design: Lessons from Designing A "Green Map" [32]
- Using ICT for Climate Adaptation and Mitigation through Agro-Ecology in the Developing World [44]
- Sustainable food systems with ICT [45]

4. Equity and diversity over homogeneity

Equity is at the centre of the ethical imperative that is the basis of sustainability. Diverse systems are resilient systems. The call for diversity can be seen to be in tension with the need to transform to sustainability at scale. But it does not mean a homogenous one-size-fits-all solution. Pita Tipene describes this well: "I think that we're all seeking to be a global community and to be truly global we need to both cultivate, strengthen and enhance the small villages that we have throughout the world. To retain that uniqueness and unity through diversity as a key." [43].

Most papers in the ICT4S Corpus do not address equity and diversity at all. Those that do include Gui's discussion of Transition Towns [34], and von Heland's [45] work on scenarios for smart and sustainable water futures in Nairobi, Kenya - included here not because of the Global South context, but because of the inclusive approach taken to the notion of the citizen field engineer.

Knoll's [41] approach to inclusive mobility planning is a useful example from the application of ICT4S to transport. They argue that active modes of transport, such as walking and cycling, exhibit a wide range of ecological, economic and social benefits for individuals as well as for societies and their focus is on "mobility conditions, empowerment and social inclusion, especially for people with physical limitations, the young and the old as well as migrants". They approached this by developing a "multi-perspective ICT tools and service kit to be used for activating residents, analysing mobility-related framework conditions and assessing the supposed impact of different planning options" with the goal of "supporting local decision-makers within the early phase of mobility planning, in order to strengthen knowledge and competence as well as to remove barriers to sustainable and active mobility".

5. Respectful, collaborative responsibility over selfish othering

Rather than shifting responsibility onto others, we need to accept responsibility and address the issues together. Note, however, that one shouldn't be don't get misled by "collaboration" in the statement here. This element is not is not just participation (that is covered in #8) but a shift in values. Oxfam described a "global citizen" (p. 68) who is, amongst other things "aware of the wider world and has a sense of his or her own role as a world citizen", "outraged by social injustice" (p. 68) and takes responsibility for his or her actions [46]. Using the term "outraged" takes value-based and action-focused further than other such statements. This is, of course a value statement, their "citizens" are not passive but can be described as having a "sense of identity and self-esteem…a belief that people can make a difference" (p. 69) [37]. They back these attitudinal statements with skills in critical thinking; an ability to argue effectively; an ability to challenge injustice and inequalities; and cooperation and conflict resolution.

To what extent then, does ICT4S support this sense of collective? While several papers hint at this collective ethos, there is a tendency for this to seem almost coincidental, or perhaps a fortuitous side-effect of a participatory method or efficiency through crowdsourcing e.g. [47]. Community level energy schemes are in this collective space. For example, Denward [48] unpicks the relationships between adaptive notions of comfort, and the current paradigm of changing individual behaviour and load control "rethinking the individual-oriented energy feedback mechanisms and explore collective dialogue processes instead". Also in the community energy arena, Ferrario [5] aimed to engage the

community in a process of developing an understanding of their relationship with energy. Weeks [51] meanwhile reconsiders individual behaviour model and describes collective models for motivating energy saving retrofitting.

With a few exceptions - those above and Gui's Transition Town work [34] - this element is a missed opportunity for ICT4S. New researchers starting out in ICT4S might want to examine the attributes of Oxfam's Global Citizen and ask how computing might help with that. What does ICT4S's 'Sustainable Citizen' look like and how can researchers and practitioners

6. Action in the face of fear over paralysis or wilful ignorance

In the face of wicked ambiguity, we still need to take considered action rather than suffer paralysis or passively wait for miracle cures. We should also avoid action linked to wilful ignorance (or denial). This is about getting on and doing, but needs to be considered alongside humility (#10) and living positive futures (#9). We need to actively do things for the good, but avoid solutionism & "Yet Another Platform" (Walker [32]).

Most, if not all, problems of sustainability can be described as trying to address "wicked problems": intergenerational time scales, complex systems – that are not amenable to the short-term, positivist approach of most interventions. Instead we need to learn to live in a complex world of interdependent systems with high uncertainties and multiple legitimate interests. These complex and evolving systems require a new way of thinking about risk, uncertainty, ambiguity and ignorance [39]. These systems require that we can think simultaneously of drivers and impacts of our actions across scales and barriers of space, time, culture, species and disciplinary boundaries.

A first direction for ICT4S in this regard is to support initiatives that are actively making a positive difference - von Heland's [45] support of crowdsourced water engineers in Kenya is a good example (so too is Knoll [41]). Transition Towns could be more than a source of inspiration, they could also be a site of ICT4S activity (Gui [34], for example [51]).

A second direction is to get busy and get computing's own house in order - preferably in ways that align with other elements in the Transformation Mindset ([55], [40]). Educating all computing practitioners to think and act sustainably is an important step (e.g. [8]).

A third direction for ICT4S to support sustainable decision making. Stefan [50] describes how most decision making is based on deterministic analysis that ignores uncertainty. This is particularly problematic as the holistic thinking required for sustainability means bringing externalities inside, which increases uncertainty. Increasing spatial and temporal scope further increases uncertainty - and often these uncertainties are not that which more data will resolve. Stefan describes business tools which derive the information needed by a decision maker based on a number of characteristics: 1) the organisation's sustainability goals; 2) the decisions to be made; and 3) statistical decision analysis to support multi-objective decisions under uncertainty.

7. Values change over behaviour modifications

In order to make meaningful long-term changes, there needs to be a shift in values, rather than just addressing harmful behaviours. Intervention that achieves behaviour change without corresponding values is likely to not be as effective due to dissonance felt by the individual.

Sterling describes the importance of critical reflexivity – or deep questioning of assumptions. This reflexivity, or self-reflection is crucial to the transformation mindset – we need people to care: "First you have to care," argued Atkisson as the first step towards sustainability (p. 16) [54]. We need to embed sustainability itself as a core cultural value.

While we have not analysed this in detail, it appears that the dominant change lever in the ICT4S Corpus is individual behaviour change - motivated by persuasion through information and/or monetary incentives. This is despite several influential papers in the wider literature, notably Brynjarsdottir's [58] "unpersuaded", Knowles' [59] discussions on values and Silberman's bringing these two arguments together [60].

It could be argued that this values basis of sustainability makes it inherently unsuited to computing. Zapico [61] describes how sustainability is a normative concept, building on ideas such as justice, equity and responsibility, and based on human culture and society. This does not sit well with a machine (and a science) that deals with quantitative data" and can lead to "data blindness" which he describes as "the risk of trusting only or too much in data". Combined with the basis of computing as a development science - focused on innovation and newness - a sustainable value set for computing might be an impossible dream. Fortunately, many of the papers described earlier, successfully dream this dream: Ferrario's community work ([5]), Gui [34], Joshi [40], Walker [32]. Even if this is a dream too far for some ICT4S researchers, it would be beneficial to at least be aware of the risks and limits of behaviour change ([62], [63], [64]).

A values basis can be the basis for successful business. Wishbone Design Studio [65], for example, produces children's bikes. On Willard's sustainability maturity model [18], Wishbone is operating at the highest level, a values basis where "sustainability-based thinking, perspectives, and behaviours are integrated into everyday operating procedures and the culture of the organization" (p. 31) [18]. Wishbone is values-led, entirely based on a framework of sustainability and quality. Wishbone's primary product is a bike that lasts from ages one to five, and then can be passed on to the next young rider. The role of values infuses the business and the relationship with customers "because we declared our values early on – sustainability and quality – we were attracting customers of that same ilk, the pressure on us was not to drop standards, but to raise them" [65]. The challenge for computing is to develop a similarly values-led business model.

8. Empowering engagement over imposed solutions

By empowering individuals and groups, and ensuring that they are engaged, any actions that are taken are likely to be more successful than if 'outside experts' impose solutions. Working with, rather than about, is vital. Ensure that solutions are case specific and appropriate, rather than a 'catch all'. Actions should be: collaborative; participatory; equitable; open; trusting and supporting of ownership. Building self-reliance should be a goal.

There is evidence of this engagement approach in the ICT4S Corpus. Some we have discussed already: Knoll [41], Gui [34] "engaging community-level sustainable practices requires sustainable HCI to encourage strategic collaboration between community members", Joshi [40], and von Heland [45]. Walker [32] describes the "value of participation in processes rather than creation of technology products". This participation must not be a token but has at its core "moral and pragmatic design propositions–that users adopting the design outcome have a right to be included and should be included, in order to increase chances of success". Participatory approaches move away from an orientation that sees "user practices and attitudes as problems to be 'solved' rather than drawn upon".

For Kramers [66], citizen participation is the essence of the smart sustainable city (see also Ringensson [67]). The participation they envisage goes beyond the ICT enabled transparency, communication with authorities, online voting and so on, to a networked form of governance. This is a different take on "smart" from the usual automation and, dematerialisation, and aligns with the work of von Heland in Kenya where "smart water management" is as much about participation and governance as it is about sensors on pipes [45].

9. Living positive futures over bleak predictions

While doom and gloom predictions can help jumpstart action, there needs to be more of a positive outlook in order to motivate and capture change. We take an optimistic frame. It is easy to become negative about sustainability. To do so, however, is to miss the point. The focus of sustainability is on the solutions, not the problems. Sustainability is the solution to living beyond planetary boundaries and a finite number of resources.

Orr argued that "the study of environmental problems is an exercise in despair unless it is regarded as only a preface to the study, design, and implementation of solutions" (p. 94) [68]. Schendler makes an important distinction [69]. He says it is vital that we do not see the challenge (in particular climate change) as the end of the world. Instead we can see "an opportunity on the scale of the Enlightenment or the Renaissance, a rare chance to radically change the face of society forever" (p. 46) [69]. This is not to deny the problem. Rather, we would argue for demonstrating positive alternatives: transition towns, or co-housing initiatives, for example. Scott argues that the problem with the green movement is that "they assume, falsely, that change is achieved by brute logic [70]. Change is not achieved by brute logic. It's achieved by, in fact, listen, link, leverage and lead." In other words, by leading positive change.

Ochoa-Ochoa [71] describe how a growing disconnection (distanciation) from the fate of the natural world stems from a cyclical process whereby "environmental crises —as represented by the media— causes despair and denial, limiting participation in societal-level conservation interventions and decreasing the effectiveness of conservation actions". Ochoa-Ochoa propose a strategy to reverse distanciation, to moving beyond what might otherwise be seen as a futile struggle "conservation desperately needs to retain hope and, conversely, it is absolutely crucial to avoid despair".

We discuss this need for a positive future in [72]. Papers discussed previously either similarly argue for a positive response (such as [34]) or are useful examples of this: Eriksson [8], Weeks [56], von Heland [45], and Knoll [41].

10. Humility and desire to learn over fixed knowledge sets

The desire to learn has several implications or variations: humility over willful ignorance; curiosity over fixed cognitive maps; challenging assumptions over accepting status quo. This then, is a learning mindset in line with Senge's 2008 argument that everything we do is a learning opportunity [73] and Orr's description of the role of an ecologically literate population [68]. Such people, he argued are "able to distinguish health from its opposite and to live accordingly" (p.108). A mission of education is to give something that "will equip a person to live well in a place (p. 151) [48]. But we should never be fooled into thinking we know it all.

> "Caught between the infinite promise unleashed by technology proliferation and the unprecedented scale of resource depletion, waste and inequity, we inhabit a space where critical alternatives are sought more than ever" Joshi [40].

The mindset, then, emphasises a curiosity and questioning – a desire for knowledge, but a firm belief that we can never know all the answers. This is critical but we must remember that this is not a synonym for negative.

There are several ways in which this humility can provide a basis for ICT4S research. For example, challenging the assumption of business-as-usual unfettered growth (and that IT/business need not be concerned e.g. Laubacher [47] Bates [16]) and where responses include responses include design fictions Penzenstadler [52], and scenarios [33]. Or challenging the idea that smart equals sustainable (Rivera [50]) or questioning where we should put our effort (Pargman [78]). Or assumptions that ICT

is solution (Zapico [61], Walker [32]) or the central part of the solution (von Heland [45], Gui [34]), that net effect of ICT4S is always positive (Batchelor [74], Coroama [75]), or that responding to climate change is relatively simple Shabajee [31], easily calculated (Hankel [77]) or merely providing information to change behaviour Cakici [76].

6 Conclusion

ICT is a major social force and we can hardly hope to achieve our ambitions for sustainability without a mature ICT4S. While we did not explore this in any depth here, it would be interesting to know to what degree the shortfall that we have identified is due to a lack of interdisciplinary - specifically a disengagement in the broader sustainability movement. Or are they just reacting to change happening elsewhere and playing catchup?

As indicated in 2.3 above, there are two aspects to "shifting the needle", the maturing of the research described here and a roadmap for activities to bring that change about. These would combine into future research in examining potential big ticket opportunities for ICT4S to make truly transformative change. Not just optimising major unsustainabilities (e.g. transport), but social transformation (participatory digital democracy and its pitfalls), and a transformation from material consumerism into digital consumerism (with inherently lower material demands).

The ICT4S conference series aims to bring together "leading researchers in ICT for Sustainability". The premise of this paper is that the ICT4S demonstrated by the corpus of this conference, is unfortunately, insufficient to deliver a meaningful change towards a regenerative socioecological transformation. We have presented an analysis of the ICT4S corpus which backs this view – as a research community and as humans, we need to do better – we need to shift this needle. We have then presented an analysis of the corpus on a Transformation Mindset which shows a similar paucity in terms of sustainability. We then described the individual elements of the Transformation Mindset in relation to ICT and presented previous research initiatives that address some or all of these elements. Our hope is that this paper will be seen as an opportunity for ICT4S researchers examine their own research and ask themselves how they could contribute to a shifting of the needle towards ICT4S truly contributing to a positive socioecological transformation.

We came, we took stock, we highlighted shortcomings and identified a number of opportunities. Now, join us on this journey towards a transformative ICT4S by challenging yourself, your colleagues and the communities you publish at to a rigorous discussion about shifting the needle towards more mature research that breeds positive transformation.

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