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Anticipating IR 4.0: Conceptualising a human-centred contribution to the design of emerging complex technological systems

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Abstract

Emerging IR 4.0 systems have the capacity both negatively and positively to disrupt. While currently much of the design in this regard has for practical reasons focused on technical systems, there is an urgent need to ensure that these systems due to their physical fabrication, pervasive deployment, and autonomous capabilities, are integrated into our human world in a manner that enhances the human condition and ensure planetary sustainment. Supporting this urgent need, this paper suggests that human-centred design (HCD) can make a substantial contribution, albeit with a recasting of its traditional design role. Consequently, HCD is positioned as an anticipatory mode of research focused on developing both plausible future scenarios, as well as recognising potential enabling activities and contexts for reaching or avoiding these scenarios. Exemplifying, this type of anticipatory inquiry, a scenario detailing a possible human-centred approach to IR 4.0 systems design is provided. The scenario is complimented by an introductory range of suggestions articulating the tactical steps that a design learning programme could implement to ensure the next generations of designers are prepared adequately to engage with the realities of the emerging technological developments.

Keywords: Anticipatory design, discursive design, design education, IR 4.0, human-centred design

Introduction

In the *Fourth Revolution* (2014), information philosopher Luciano Floridi suggests that the future of human reality will be shaped by the growing pervasiveness of digital and physical cyber systems. Many of these systems that Floridi refers to can or will be regarded as 'third-order technologies' capable of autonomous behaviour and seemingly intelligent behaviour.

In fields of design associated with product design, such as industrial and interaction design, the technical knowledge required to engage with the internal material dynamics of third-order technology meaningfully and directly is for most practitioners beyond their know-how. In this sense, many of the emerging cyber technologies of the fourth industrial revolution (4IR) have fundamentally rolled back the democratisation of digital technology that emerged during the Third Industrial Revolution (3IR), requiring advanced specialist technical knowledge to both conceive of and implement strategic intentions. Thus, the development of these technologies typically falls under the remit of technology-centred professionals such as software engineers and computer scientists.

In response to this brief problematisation, this paper explores first, how human-centred design (HCD) approaches can meaningfully impact the design of technology at the level of complexity presented by

third-order technologies and second, presents a set of requirements that can strategically guide design education to anticipate this emergent need.

The methodological approach of this study is premised on Inayatullah's 'six pillars of future thinking' (2008). As such, the first section of the paper 'anticipates' and 'deepens the future' of a human-centred commitment to design in the age of 4IR by providing a brief outline of key technical characteristics of emerging technologies, as well describing valuable design and futures orientated approaches for considering such technologies. The second section 'engages with alternatives' by presenting a brief a scenario describing a HCD approach for engaging with large-scale technological systems associated with concepts such as the IR 4.0, and smart cities (collectively referred to as IR 4.0 systems).[1] Lastly, the third section 'backcasts' from the proposed scenario a suggested set of criteria for design curricula, seeking to address the impact of IR 4.0 systems.[2]

Section 1: Anticipating the role of HCD in the 4IR deployment

This paper is foremost concerned with a role that HCD as a socio-cultural practice can bring to the development of highly sophisticated large-scale technological systems associated with IR 4.0. At the time of writing, it is evident that these techno-visions of our immanent future have given rise to a great deal of anxiety around their implementations. While not necessarily misplaced, this anxiety is often compounded by a poor understanding of the composite technologies likely to enable emergent IR 4.0 systems. Hence, while this paper is primarily concerned with a scenario in which human-centric design is applied to lessen the likelihood of these social anxieties materialising, this initial discussion will introduce and briefly contextualise a broad technological framing of IR 4.0 systems.

At an essential level of understanding, IR 4.0 systems can be defined by the differences between first, the Third (3IR) and fourth industrial revolutions, and second, the characteristics of *first*, *second* and *third-order* technologies.

3IR (often referred to as the digital, computer or information revolution) is typically characterised by the ubiquitous use of computational technologies in both the work, home and mobile. From a technological perspective, 3IR includes hardware such as personal computers, mobile devices, 3D printers utilising the networking infrastructures of the world wide web, and largely focuses on the communication of information.

In turn, IR 4.0 systems are defined by their third-order technology abilities.

Floridi (2012, p. 27) describes *first-order* technologies as characterised by a direct relationship between people, technology, and the natural world. For example, if one uses a garden spade to dig a hole in the ground.

In *second-order* technology, an individual's engagement with one technology is mediated through the use of an 'in-between' technology. For example, the use of a key to open a gate. Here, the key is the technology 'in-between' the user and the gate.

Lastly, in *third-order* technology, the human-user sits outside of 'the loop' of at least one technological order. This inner-loop involves at least one primary technological 'agent' initiating the use of a different secondary technologies that may in turn, mediate a third level of technologies (Floridi, 2014, p. 29). These third-order technologies act and interact 'intelligently' in the sense that they "process information logically and autonomous" (Floridi, 2014, p. 94). In this manner, third-order technologies, while associated in popular culture with artificial sentient intelligence, are more accurately

[1] IR 4.0 refer specifically to 4IR as applied to industrial settings.

[2] 'Backcasting' is a method of 'reverse engineering' the activities and conditions that need to be in place to increase the likelihood of a particular scenario of the future occurring (Inayatullah, 2008, p. 18).

exemplified by engineered intelligence concepts such as machine-learning, neural networks, situated robotics and light IA.[3] Consequently IR 4.0 systems can be understood as relating to both a new manufacturing society in which data and information have superseded raw materials and energy as the real source of added value, and the digital fabrication of a world in which humans are no longer the sole intelligent actors (Floridi, 2014, p. 218).

Consequently, IR 4.0 systems, which often make use of 3IR hardware infrastructures, are differentiated by their highly complex abilities to absorb, process, and autonomously respond to data at unprecedented scale and levels of sophistication.

While this explanation of IR 4.0 systems and the three orders of technology is purposely introductory, three further points are relevant to the general discussions.

First, and fairly evident, is that emerging digital technologies and infrastructure, be they 3IR or 4IR, are highly complex technical environments and are becoming ever more so.

The second, less apparent point is that IR 4.0 systems are largely projections of a future. They do not as yet exist. In this sense, much of Klaus Schwab's *The fourth industrial revolution* (2016) is written in the future tense, Floridi's *Infosphere* is a futural place where IR 4.0 systems have become pervasive, and our cities are at best trying to be smart (Snow, et al., 2016, p. 92). This is not meant to be a provocative statement but rather to suggest that much of the seed technology for these visions has or is in the process of been developed and while isolated examples exit, it is far-fetched to suggest our everyday experience of the world pervasively exceeds 3IR. This is particularly true of African contexts where for many 3IR remains aspirational, for as Schwab (2016, p. 8) notes, more than 1.3 billion people on the planet still lack access to electricity.

Thirdly, while IR 4.0 systems are for now 'futural', they are on the technological horizon. Thus, there is every indication that our emergent work, home, and urban experiences will converge with these technological environments. For unlike the digital technologies of the 3IR, those of 4IR will be fabricated directly into the physical environment. In this manner as Floridi cautions, our "physical and conceptual environment" will be overwhelmingly an artificial one, shaped by often invisible and opaque technologies.

Consequently, there is a chance that these pervasive techno-environments, which will define our future human condition, will be driven by technological concerns such as what is "the best or easiest, or indeed sometimes the only, way to make things work" (Floridi, 2014, p. 150). However, if considered properly, these technologies do provide the opportunity for us to address the problematic state that our previous 100-odd years of technological advancements have brought about. For example, we have the opportunity to ensure our cities are more sustainable, our food chains more productive, and our education systems more accessible and equitable. To achieve this, Floridi advocates the role of "human intelligent design" to shape the future world and our human experience within it (Floridi, 2014, p. 150).

Philosophical approaches to design

As noted by several researchers, contemporary design can be categorised into different approaches, each suggestive off a particular set of philosophical concerns. Krippendorff (2006) and Giacomin (2014), for example, both recognise the design paradigms of technology-centred design (TCD) and human-centred design (HCD), while Giacomin adds a third, environmentally sustainable design.

[3] See Floridi (2014, pp. 141-143) for further explanations regarding 'light' and 'heavy' IA.

Technology-centred design

TCD is primarily concerned with technical novelty (Giacomin, 2014, p. 607) with an emphasis placed foremost on the ability of a technical system to perform a prescribed objective. In this discussion, TCD is associated with disciplines such as information science, engineering, city planning and computer sciences.[4, 5] From a historical perspective, TCD can be understood as emerging during the industrial era, placing its design focus on product functionality.[6] As such TCD is historically influenced by a range of theorists, including Buckminster Fuller, Sydney Gregory and perhaps most famously Herbert Simon and his 'science of the artificial' (1982). TCD typically uses *design science* methodologies, which inherits much of their knowledge from the sciences and typically emphasises objective approaches to research yielding generalisable results (Buchanan, 2007, p. 57).[7] In this manner, TCD amounts to shaping the future world but is not typically concerned with shaping the human experience within it.

Critique levelled at TCD is that it tends towards a deterministic technological viewpoint based on the rationales that "technology develops autonomously and by its own logic", and a framing of technology as culturally neutral, implying that people can and should adapt to any resulting change (Krippendorff, 2006, p. 13). However, it is worth noting that much value in the world originates in the ingenuity and innovation that originates in TCD.

Human-centred design

At its broadest definition, HCD is a philosophical paradigm of design that situates the practice as foremost a social activity orientated towards supporting peoples' conceptions and desires, and as such cannot be separated or abstracted from the context of their lives (Krippendorf, 2007, p. 71).

Historically, HCD emerged from a varied range of disciplines. For example, Victor Papanek, an early influential industrial designer proponent whose seminal publication *Design for the Real World* (1971) questioned design's commercial agenda. Other notable critiques of design practice at this time include architects and urban planners Horst Rittel and Melvin Webber (1973), who collectively recognised the need to address social complexity when considering urban infrastructure. Likewise, in the field of human-computer interaction, albeit slightly later, influential scholarships such as Lucy Suchman's work on situated action (1987) and Winograd and Flores's *Understanding Computers and Cognition* (1987) suggested the design of computational technology be reliant on the relations among and between people and the "culturally constituted worlds that they inhabit" (Rogers, 2012, p. 45).

HCD acknowledges that designers are first people and as such, participate in the social constitution of reality, both in terms of what they produce, as well as how they produce it. Consequently, designed products contribute to knowledge in the world, but also must be understood as perpetuating specific knowledge dispositions pre-existent in the world. In HCD the emphasis is, thus, placed on the designer to ensure (to the degree that they can) that their worldview does not obscure that of the community, expected to use the resulting technologies. In this manner, the resulting technology is required to respond to the lived experience of people, not disrupt it.

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[4] Don Norman's The Design of Everyday Things (1990) is a seminal text that critiques technological determinism in design

[5] The remainder of this paper uses 'technologist' to collectively describe professionals from these fields.

[6] As outlined in *Making the Modern* (Smith, 1994).

[7] See Hevner, et al. regarding Design Science (2004).

Therefore, from a paradigmatic viewpoint, HCD can be understood as interrelated set of philosophical, epistemological, and methodological approaches to design, geared towards a consideration of the people who perceive, interpret, use, and live with designed artefacts (Krippendorff, 2000, p. 4).

HCD is not immune to criticism. First, while HCD often claims to represent the lived experience of people, in practice it is often characterised by poor application and understanding of ethnographic methods adapted from the social science (Baskerville & Myers, 2015, p. 28). Second, in commercial practice, HCD has often been deployed to enable unethical business and social engineering practices.[8] Third, HCD's emphasis on human experience as the primary criteria for evaluating the validity of design has become a growing concern as the harrowing effects of climate change become apparent (Russel & Lyndon, 2020, p. 3). While one could argue that many of these problematic aspects arise from a misunderstanding of the intent of HCD, often brought upon by the appropriation of the term by design consultancies foremost concerned with innovative business practices, this paper takes the position that the continuation of human existence is a direct consequence of planetary sustainment. As such, the remainder of the paper conflates environmentally sustainable design with HCD.

The shortfalls of TCD and HCD in terms of IR 4.0

While TCD and HCD present distinctly differing philosophical views for approaching design their relationship should not be viewed as oppositional or absolute. Hence, for example, it would be naïve to suggest that engineers never have any regard for human-users or that UX designers have no conceptualisation of programming structures. While both approaches have their individual drawbacks, a more helpful view is to consider TCD and HCD in relationship to what multiple authors have referred to as designing for the 'inner' and 'outer' loops or environments of technology (for example, Floridi, 2014; Simon, 1982). In this manner, TCD can be associated with inner-loop design, which can be understood as focused primarily on the development of the internal structure and operations of technological systems. In comparison, HCD can be conceptualised as addressing outer-loop design and, as such, is concerned with how technologies interface outwards, towards people, and, reciprocally, how people interact with technologies. Consequently, and exemplified in the contemporary digital industry, it is reasonable to suggest that most technology benefits from the consideration of both loops of design.

However, due to the scale and complexity of emerging IR 4.0 systems there are few HCD designers directly involved with their design. This is unsurprising for two interrelated reasons.

First, as emerging technologies much of the current concern is focused on system functionality rather than a specific real-world application. In this manner, these technologists are still largely resolving general problems as opposed to contextual ones.

Secondly, HCD, particularly within its concern for specific user-communities typically is contextually located and idiographic in nature. Therefore, HCD tends to not scale easily to the level of the types of general problems currently required in the TCD of IR 4.0 systems.[9]

The consequence of the absence of outer-loop design is that these systems are currently largely conceptualised from technologically orientated frameworks. Consequently, design decision-making is

[8] This type of unethical persuasive design is often referred to as 'dark pattern' design.

[9] As noted by Mani-Kandt (2021), HCD struggles to resolve complex, large-scale systemic problems.

at worst driven by technocentric views, and at best, by professionals with little, if any, training or sensitisation to guide implementation in the social world.

Unlike previous generations of digital technology design, IR 4.0 systems will be fabricated into the built environment of our surrounding cities, homes, workplaces, and vehicles. This physicality implies that the ability for the outer-loop design to catch up with the inner-loop will be drastically curtailed due to among other criteria, extremely high costs. Thus, there is an urgent need for design approaches that are concerned with the impact of IR 4.0 systems from socio-cultural and planetary perspectives to contribute meaningfully to their development. Failing this we may find ourselves set on a path from which there is little chance of deviation. For as noted by Townsend (2013) Greenfield (2017), Zuboff (2019), we may soon find that the very businesses that currently control and profit from social media will be designing our homes, workspace, neighbourhoods and cities.

Discursive speculations

While product design fields such as industrial, interaction and user-experience design have contributed much to the human-centric design of contemporary digital technologies, this contribution is typically limited to tactical concerns such as usability and directly embodied experience. These fields have largely embraced HCD in terms of what Baskerville and Myers (2015, p. 27) refer to as *ethnography for design* (E4D) characterised by user-studies involving research methods such as interviews, observations, participation, among others. More recently, fields such as service design (Polaine, et al., 2013) and strategic design (Nixon, 2016) have been deployed at a broader scale of focus to direct organisational service offerings from a strategic perspective. These fields have tended to expand on E4D methods to account for their human-centric positioning, albeit often within the limitations of corporate or governmental organisational contexts, short-term temporal considerations, and restricted to preferable and implementable change.

Outside of E4D practices of HCD, there is a growing set of discursive design (DD) practices that collectively seek to explore alternative future states.[10] While sharing a legacy with other historical design practices, DD came to prominence through the extensive contribution of Dunne and Raby (2001) (2013), as well as other influential researchers such as Gaver (1999) (2001) Sterling (2005) (2013), Bleeker (2009), Malpass (2013) (2017) and more recently Tharp and Tharp (2018).[11]

While DD is a rich and varied field, there are multiple aspects that resonate with outer-loop design in terms of IR 4.0 systems.

First, the defining attribute of DD is its application of design creativity to communicate ideas, generate debate, and change mindsets rather than the creation of utilitarian products typically associated with routine design practice (Tharp & Tharp, 2018, p. 7). In this manner, DD is not overly concerned with implementable and usable product design but rather seek to orientate its audience towards a particular viewpoint or understanding.

Second, Dunne and Raby specifically connect DD with the use of design as "a means of speculating how things could be" to open up novel perspectives on complex, social problems in order to enable and generate discourse about "alternative ways of being" (2013, p. 2). In this manner, DD often makes uses of future scenarios that extend beyond any short-term expectations of the future in order to free up considerations of how life could be, from how life is (Dunne & Raby, 2013, p. 6).

[10] Arguably, the most well-known of these practices are *critical design*, *speculative design,* and *design fiction.*

[11] The use of 'discursive design' as a composite term for these types of speculative design originates in (Tharp & Tharp, 2018).

While largely driven by the imagination, best practice in DD suggest the use of theoretical frameworks and/or consults with external expertise to envision the deployment and impact of possible future socio-technology scenarios in everyday use (Malpass, 2013, p. 338). Thus, while not without rigour, DD's focus on speculation allows for designers to engage with technologies that are either inaccessible or are themselves largely in the state of conceptualisation in order to account for "the domestication of up-and-coming ideas in the sciences and applied technology" (Malpass, 2013, p. 338).

In this manner, DD does appear to speak directly to the role that outer-loop design could take as a mode of enquiry into the various permutations and effects of IR 4.0 systems. However, DD does present several drawbacks that limit its direct application to the consideration of IR 4.0 systems. Chief, among these is that the conceptual thinking at the centre of its design activities is overwhelmingly designer-driven. As such, many of the suggested alternative futures are highly subjective reliant on personal viewpoint with very little evidence of academic rigour (Tharp & Tharp, 2018, p. 306). Second, DD does not seek to address probable outcomes but rather focuses on the limits of what is realistically possible, so as to "unsettle the present" (Dunne & Raby, 2013, p. 88). As such, DD does not, and never claims to predict a plausible future. Third, DD describes itself as an audience-centred practice, however, this audience is often only vaguely identified (Tharp & Tharp, 2018, pp. 236-7). In this manner, DD while often including technologists in consultant roles, does not place an emphasis on communicating its discourse to this audience.

Anticipating futures

The emerging field of *anticipatory design* (AD) (De Smet & Janssens, 2016; Morrison, 2018; Hunt, 2019) shares many foundational concepts with DD in terms of applying design practice to both speculate on, and create discourse around, alternative future states. However, in comparison to DD, AD is concerned with the "implications of plausible near futures and in doing so allowing designers and their designs to match the velocity of the future before critical impacts occur" (Lindley, et al., 2015 , p. 58). In this manner, AD uses DD's temporal divergence from the reality of the present but does so with in touching distance of the present. Consequently, AD is concerned with plausible emerging events and technological developments.

In addition to emphasising the plausible, approaches to AD such as *anticipatory ethnography* (Lindley, et al., 2014; Lindley, et al., 2015) apply HCD E4D methods of enquiry, and consequently, include a level of rigorous exploration into the life-worlds of particular communities. As such, AD embraces ethnographic knowledge but not at the exclusion of larger cultural and planetary concerns.

However, one issue that AD does not address adequately is the issue of an expected audience. In this manner, while many AD projects anticipate change, they tended to focus on building consensus with affected communities rather than communicating specifically to those who have the capacity to affect change. For example, Morrison's (2018) work with a community highlighting the change that global warming may bring to the Artic.

In the scope of IR 4.0 systems design, there is a very specific audience consisting of technologists whose work has the potential to be enriched or supplemented by articulate and rigorous enquiry into future social impact and possibilities for these emerging technologies.

Importantly, this is not a novel concept. The broad field of *futures studies* (futures) an interdisciplinary field intersecting with the humanities, natural sciences, politics, and design (Ollenburg, 2019, p. 51) has positioned itself in this role. In particular, and sharing multiple similarities with AD, *critical futures* scholarship recognises 'the future' as inherently a domain of ideation and imagination, which while incapable of being directly experienced has "real and material consequences" (Candy & Kornet, 2019, p. 5). As such, much like DD and AD, critical futures employ "the design of situations and stuff from the future to catalyse insight and change" (Candy & Dunagan, 2017, p. 137).

The recognition of the conceptual overlapping of DD, and particularly AD with critical futures is in the scope of this discussion important for two pertinent reasons. First, the field of futures positions itself as a consultancy practice. In this sense, futures offer a range of skills and concepts focused on articulating alternative scenarios for describing future possibilities. Importantly, while futures thinking may suggest the necessary steps for any one scenario to unfold, it makes no claim in terms of delivering the projected futures. In this manner, futures plays an advisory role rather than an artefactual productive one and, as such, is deployed as a service to a client entity.

Second, critical futures provide multiple theories that can provide a level of conceptual substance to inform outer-loop design that focuses on anticipating emergent IR 4.0 systems. These include, for example, frameworks such as Inayatullah's *Six Pillars of Futures Studies* (2008), Candy and Kornet's *Ethnographic Experiential Futures* (2019) and Ollenburg's *Futures-Design-Process* (2019).

To conclude this section's discussion, while IR 4.0 systems can be considered highly complex and at this stage developmental, there is an urgent requirement for these systems to be anticipated through a human-centred lens in order to highlight concerns and generate dialogue as to the best way forward before their physical implementation lessens the opportunity to do so. Consequently, the next section presents a brief scenario, describing a possible approach.

Section 2: A scenario of anticipatory design 4.0 (AD 4.0).

AD 4.0 can be described as a philosophically humanity-centred, design-led approach to research concerned with the generation of plausible design speculations that explore from a socio-cultural and planetary lens, the potential impact and opportunities presented by emergent IR 4.0 systems.[12]

AD 4.0 exhibits the following characteristics. First, AD 4.0 uses the processes and material qualities of design to explore and communicate concerns and opportunities. In this manner, it can be closely associated with discursive approaches to design. However, unlike most DD projects AD 4.0 is foremost a research activity.

As such, AD 4.0 contributes knowledge in service to other technologists involved in the TCD (and decision-makers) of IR 4.0 systems. In this manner, AD 4.0 uses its discursive nature in support of routine design practice and does not explicitly seek to resolve problematic situations through artefactual production. Consequently, AD 4.0 doesn't suggest how a system should operate but rather how they should behave.

AD 4.0 is communicative; it recognises that its audience are technologists and is mandated to communicate its discourse in a manner accessible to this audience. To this point, AD 4.0 anticipates the impact and opportunities of emerging technology through both the generation of exploratory scenarios, as well as in articulations of potential routes for achieving or avoiding identified scenarios. Supporting this intent, AD 4.0 is both persuasive and able to articulate how idiosyncratic attributes of individual designs can be generalised at least to a level whereby they can be applied to or attuned to other design contexts.

Section 3: Backcasting components of an AD 4.0 orientated teaching programme

As a scenario, AD 4.0 is itself anticipatory. For while there is a need for AD 4.0 or similar approaches to engage with and respond to disruptive technological change, currently in South African design education landscape approaches of this type are at best propositional. Hence, the important question

[12] 'Design-led' can be equated with practice-led approaches including research through design and research through practice.

is: *if AD 4.0 is an aspirational scenario of the type of design practice that is or will become important and meaningful, what are the tactical actions design educators can begin to introduce into their teaching programmes?*

To answer this question, this section outlines three focus areas that can potentially develop the required knowledge and skills to engage with AD 4.0.

First, a clear proposition that discursive and anticipatory orientated design research has a role to play in advancing IR 4.0 systems and/or other complex technologies requiring consideration at community, city, regional and/or global levels must be communicated. In this manner, this requires a framing of HCD as a consultancy research activity akin to anthropology, but more suited to engaging with creative activities and industry. Design education and academic researchers are vital in this capacity. For academics practising and describing AD 4.0 activities are vital for extending knowledge in this developing area. For educators, positioning design-led research as a valuable and viable career focus is important. Collectively, with the practitioner community, design educators and academics need to be able to narrativise these abilities of HCD to other stakeholders.

Second, while staking a claim in these regards is important, developing conceptual abilities to conduct AD 4.0 type practice is fundamental. As an initial starting point, the following inclusions are suggested:

1. A range of conceptual frameworks that account for a rigorous and in-depth understanding of emerging technological developments, social accounts of technology and lastly, critical theories that specifically address the previous two points are required. Consequently, human-technology studies should be a core aspect of a HCD education.
2. A rich and detailed understanding of social contexts is mandatory. This implies an engagement with social and anthropological theory, as well as a fundamental understanding of other forces which may impact futural states such as politics, economics, and histories.
3. Conceptual frameworks that prioritise planetary sustainment or a non-negotiable consideration.

Third, design practices that emphasise scientific rigour and imagination, strategical and tactical thinking, as well as knowledge generation at both idiographic and general levels should be included.

In terms of scientific rigour, the teaching of ethnographic research methods must ensure resulting insights are relevant and valid. Failing this, it will remain hard to convince other stakeholders that subsequent anticipatory work has any merit.

In order to develop student's design imagination, projects with speculative concerns should take place in addition to projects with routine design concerns. The central point is not to develop practitioners of DD per say, but to develop students' thinking skills to extend beyond overly rational, problem-solving approaches. While conceptual approaches such as 'blue-sky thinking' have long been applied, utilising the frameworks presented in critical futures (and possibly other approaches to futures) can help to create more credible futures scenarios.

To develop strategical and tactical thinking, product agnostic design approaches such as service design should be practised. These approaches emphasise data-driven methods that require in-depth enquiry into the particular context of the design in order to inform any subsequent design action. These types of analytical approaches can be complimented with anticipatory scenarios and the backcasting of actions required to achieve preferred scenarios.

Lastly, while the natural terrain of design practice is 'ultimate particulars' (Nelson & Stolterman, 2012, p. 39), AD 4.0 research requires the extraction of more general considerations such as emergent patterns, interrelationships, prescriptive situations, and relationships rules to be made more explicit from, and during practice. To develop these abilities, design students need to develop their skills and knowledge in the meta-structuring of information. This, the author has previously argued (Fenn & Hobbs, 2014), (Hobbs & Fenn, 2019) is the domain of information architecture, an invaluable field of practice for any designer facing design uncertainty brought on by contextual complexity.

Conclusion

Emerging IR 4.0 systems have the capacity to disrupt our current lived experience both negatively and positively. While currently much of the design in this regard has for practical reasons focused on technical systems, there is an urgent need to ensure that these systems due to their physical fabrication, pervasive deployment, and autonomous capabilities are integrated into our human world in a manner that enhances the human condition and ensures planetary sustainment.

This paper anticipates first, how E4D approaches can be combined with discursive, speculative approaches to futural considerations, in order to address the deployment of emerging IR 4.0 systems in a socially and planetary sustainable manner and second, the key design education factors that require implementation in order to ensure the next generations of designers are prepared adequately to engage with the realities of emerging technology environments.

References

Boulding, E & Boulding, K 1995, *The future: Images and processes*, London, Sage.

Buchanan, R 2007, 'Strategies of design research: Productive science and rhetorical inquiry', in M Ralf (ed.), *Design Research Now*, Basel, Birkhäuser, pp. 56-66.

Candy, S & Dunagan, J 2017, 'Designing an experiential scenario: The people who vanished', *Futures,* vol. 86, pp. 136–153.

Candy, S & Kornet, K 2019, 'Turning foresight inside out: An introduction to ethnographic experiential futures', *Journal of Futures Studies,* vol. 23, no. 3, pp. 3–22.

De Smet, A & Janssens, N 2016, 'Probing the future by anticipative design acts*',* Brighton, *2016 Design Research Society 50th Anniversary Conference.*

Dunne, A & Raby, F 2001, *Design noir: The secret life of electronic objects*, London, Bloomsbury Visual Arts.

Dunne, A & Raby, R 2013, *Speculative everything: Design, fiction, and social dreaming*, Cambridge, MIT.

Dunne, A, 2005, *Hertzian tales: Electronic products, aesthetic experience, and critical design*, Cambridge, MIT Press.

Fenn, T & Hobbs, J 2014, 'The information architecture of meaning making', in A Resmini (ed.), *Reframing information architecture, human-computer interaction series,* Chan, Springer International Publishing.

Floridi, L 2014, *The fourth revolution: How the infosphere is reshaping human reality*, Oxford, Oxford University Press.

Frayling, C 1993, 'Research in art and design', *Research Papers,* vol. 1, no. 1.

Fry, T 2017, *Re-making cities: An introduction to urban metrofitting*, London, Bloomsbury.

Gaver, B, Dunne, A & Pacenti, E 1999, Cultural probes, *Interactions,* January-February, pp. 21-29.

Gaver, G, Dunne, A & Hooker, B 2001, *The prescence project*, London, Royal College of Art.

Giacomin, J 2014, 'What is human-centred design?', *Design Journal*, vol. *17,* no. 4, pp. 606-623.

Greenfield, A 2017, *Radical technologies: The design of everyday life*, London, Verso.

Hevner, A, Ram, S & March, S 2004, 'Design science in information systems research', *MIS Quarterly,* vol. 28, no. 1, pp. 75–105.

Hobbs, J & Fenn, T 2019, 'The design of socially sustainable ontologies', *Philosophy & Technology,* vol. 32, pp. 745–767.

Hunt, J 2019, 'Anticipating future system states', *Journal of Futures Studies,* March, vol. 23, no. 3, pp. 119–128.

Inayatullah, S 2008, 'Six pillars: Futures thinking for transforming', *Foresight,* vol. 10, no. 1, pp. 4-21.

Kilbourn, K 2013, 'Tools of movement and engagement: Design anthropology's style of knowing', in W Gunn, T Otto & R Smith (eds), *Design anthropology: Theory and practice*, London, Bloomsbury Academic, pp. 68–82.

Krippendorf, K 2007, 'Design research, an oxymoron?', in R Michel (ed.), *Design research now*, Basel, Birkhauser Verlag AG, pp. 67-80.

Krippendorff, K 2000, Propositions of human-centredness: A philosophy for design, in Durling, D & Friedman, K (eds), *Doctoral education in design*: F*oundations for the future,* Staffordshire, Staffordshire University Press.

Krippendorff, K 2006 *The semantic turn: A new foundation for design,* Boca Raton, Taylor & Francis.

Lindley, J, Sharma, D & Potts, R 2014, 'Anticipatory ethnography: Design fiction as an input to design ethnography', New York, *2014 Ethnographic Praxis in Industry Conference Proceedings*, pp. 237–253.

Lindley, J, Sharma, D & Potts, R 2015, 'Operationalizing design fiction with anticipatory ethnography*',* São Paulo, *Ethnographic Praxis in Industry Conference Proceedings*.

Malpass, M 2013, 'Between wit and reason: Defining associative, speculative, and critical design in practice', *Design and Culture,* vol. 5, no. 3, pp. 333-356.

Malpass, M 2017, *Critical design in context history, theory, and practice*, London, Bloomsbury Academic.

Mani-Kandt, R, 2021, *Why human-centred design (HCD) doesn't always work for international development,* https://www.itad.com/article/human-centred-design-international-development/, viewed 28 June 2021.

McCullough, M 2015, *Ambient commons: Attention in the age of embodied information*, Cambridge, MIT Press.

Morrison, A 2018, 'Future north, nurture forth', in J Larsen & P Hemmersam (eds), *Future north: The changing arctic landscapes*, London, Routledge, pp. 119-141.

Nelson, H & Stolterman, E 2012, *The design way: Intentional change in an unpredictable world*, 2nd edn, Cambridge, MIT Press.

Nixon, N 2016, *Strategic design thinking*, New York, Bloomsbury.

Ollenburg, S 2019, 'A futures-design-process model for participatory futures', *Journal of Futures Studies,* June, 23, no. 4, pp. 51–62.

Papanek, VJ 1971, *Design for the real world: Human ecology and social change*, New York, Pantheon Books.

Polaine, A, Løvlie, L & Reason, B 2013, *Service design*: *From insight to implementation,* Brooklyn, New York, Rosenfeld.

Rittel, H & Webber, M, 1973, 'Dilemmas in a general theory of planning', *Policy Sciences,* vol. 4, pp. 155-169.

Rogers, Y 2012, *HCI theory classical, modern, and contemporary,* San Rafael, Morgan & Claypool.

Russel, P & Lyndon, B, 2020, 'Humanity-centred design – defining the emerging paradigm in design education and practice', Herning Denmark, *International Conference on Engineering and Product Design Education,* 10-11 September.

Schön, D, 1983. *The reflective practitioner: How professionals think in action*, New York, Basic Books.

Schwab, K 2016, *The fourth industrial revolution*, New York, Crown Business.

Simon, H 1982, *The sciences of the artificial,* 2nd edn, Cambridge, MIT Press.

Smith, T, 1994, *Making the modern: Industry, art, and design in America*, Chicago, University of Chicago Press.

Snow, C, Håkonsson, D & Obel, B 2016, 'A smart city is a collaborative community: Lessons from smart Aarhus', *California Management Review,* vol. 59, no. 1, pp. 92–108.

Sterling, B, 2005, *Shaping things*, Cambridge, MIT Press.

Sterling, B 2013, 'Patently untrue: Fleshy defibrillators and synchronised baseball are changing the future', *Wired*, 11 October.

Suchman, L 1987, *Plans and situated actions*, Cambridge, Cambridge University Press.

Tharp, B & Tharp, S 2018, *Discursive design: Critical, speculative and alternative things*, Cambridge, MIT Press.

Townsend, A 2013, *Smart cities: Big data, civic hackers, and the quest for a new utopia*, New York, WW Norton & Company.

Winograd, T & Flores, F 1987, *Understanding computers and cognition,* Boston, Addison Wesley.

Zuboff, S 2019, *The age of surveillance capitalism: The fight for human future at the new frontier of power*, London, Profile Books.

