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Understanding Design'S Role in Bridging Divides Towards Sustainability Transitions

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Wicked problems and the call for radical transformations

The world is currently facing significant challenges that simultaneously affect people, societal structures and institutions as well as well as the natural, planetary processes that support life (Raudsepp-Hearne et al., 2019; Rockström et al., 2009; O'Brien, 2011). Problems such as the obesity syndemic –interconnected pandemics of obesity, malnutrition and climate change (Swinburn et al., 2019) attest to the interconnected and complex nature of issues such as climate change, obesity and undernutrition. These types of problems are often described as "wicked" because of their intractability and their resistance to simplistic solutions, and because they require integrative systemic approaches that can unlock significant transformations of the structures and logics that contribute to their persistence. There is wide agreement that moving society towards sustainability will require significant changes in societal norms and behaviours, together with governance and management structures and processes. Addressing the complexity of the systemic regime shifts needed (Olsson et al., 2014) will require novel ways of approaching such challenges through greater collaboration between disciplines and the integration of different worldviews not just within academia but also from the wider society (Raudsepp-Hearne et al., 2019).

The term "wicked problems", which has been adopted to describe the complex nature of many of our sustainability issues from across different fields of knowledge (Preiser et al., 2018) emerged from a design-related perspective in the seventies (Rittel & Webber, 1984). However, historically, design has not been prominent as a promising field of knowledge and research when addressing persistent and systemic social challenges. Still, the 21st century has witnessed a shift in design's direction and popularity. From conceptualizations such as Transformation Design emerging in 2004 (Jonas & Von Anshelm, 2015) or the more recent Systemic Design (Jones, 2014) and Transition Design (Irwin, 2015), the field has been able to prove its potential to facing and facilitating changes for the benefit of society as a whole, responding to the need for systems-level change. Design's integrative, explorative and generative nature is able to address questions of directionality –or how to influence the direction of change, and instrumentality -or ways in which to make change happen. This way, it pragmatically responds to our challenges by transforming lives, narratives, systems, structures, artefacts and environments (Jones, 2014; Krippendorff, 2011; Margolin, 2015; Buchanan, 1992).

For the purpose of communicating where the contribution of design sits when addressing some of many challenges we face today, this paper seeks to offer insights about how design researchers could contribute to inter and transdisciplinary projects working towards social and environmental sustainability and resilience. To do so, a general framework will be developed to help clarify the language, roles and spaces where design skills can fit in. It will particularly develop the discussion by bridging the gaps between two of the main communities of scholars working towards enabling sustainable futures, while arguing design's potential in the adoption of a Resilience Thinking approach.

Living in the artificial: technology as mediator in STES

Broadly speaking, two important research communities are currently addressing sustainability challenges from systemic and interdisciplinary perspectives, one working towards managing

sustainability transitions –transitions of entire socio-technical systems, and the other working towards socio-ecological resilience –the vitality and stability of socio-ecological systems (Olsson et al., 2014). Although both communities describe transformations towards sustainability as consisting of multiple levels, phases and scales (Olsson et al., 2014), they adopt different approaches, frameworks and language. This results in different methods for framing research questions and for analysing and discussing the nature of change. They also draw different boundaries to the systems they focus on. Scholars working towards Sustainability Transitions (Geels, 2005; Loorbach et al., 2017; Irwin, 2015) frame their work mostly within Sociotechnical Systems –STS, while scholars working towards social-ecological resilience adopt the Social-ecological Systems framing –SES (Folke et al., 2016).

The first group focuses on the interaction between society and the human-made world which consists of material and symbolic elements such as technology, infrastructures, markets, networks, users and cultural meanings (Geels, 2005). On the other hand, SES scholars adopt a “humans-in-nature” perspective, acknowledging the deep interdependence that exists between ecosystems and society, and in particular, human dependence on ecosystem services. Both framings are understood to be focused on complex adaptive systems (Hölscher et al., 2018; Smith and Stirling 2010, as cited in Ahlborg et al., 2019) as nested, multilevel systems displaying unexpected behaviours and emerging patterns that lead to new system configurations. Beyond these similarities, Hölscher, Wittmayer and Loorbach (2019) highlight that the main differences found between these groups stem from their epistemological traditions and the communities from which they have evolved –either within the intersection of sociology and technology studies or ecology and policy (Ahlborg et al., 2019). To describe and analyse such systems, SES scholars have developed resilience theory as a way to identify risks and avoid undesirable transformations to ensure that nature’s essential services to human beings can be maintained (Olsson et al., 2014). Because of their extensive focus on ecosystems, critics have pointed out that this perspective has not deepened its understanding of some of the social dynamics that are central to transformations, in particular, conflicts of interest and power struggles, or the political implications of structural and technological change (Olsson et al., 2014).

On the other hand, scholars working towards sustainability transitions address the interactions and complexities that exist within social sub-systems and their structures –technology and institutions, to develop better tools and governance strategies that can lead to large-scale societal changes (Loorbach et al., 2017). While they recognize the role of technology in shaping our world, they tend to ignore the role of ecosystems in both enabling, affecting or being affected by such dynamics (Ahlborg et al., 2019). This framing focuses on humans as if removed from nature, excluding dynamics that pertain to the natural environment and the whole web of life. However, if we understand humans as a major force of planetary change (Steffen et al., 2011; Folke et al., 2016), more attention is needed to the often neglected interplay between the artificial realm –technology– and its interaction with natural ecosystems.

Ahlborg et al. (2019) argue that given that both communities have failed to fully integrate some aspect of reality when drawing their system boundaries, they would both benefit from integrating each other's contributions. To close the gaps between both frameworks, they suggest adopting a socio-technical-ecological systems –STES– approach instead. This analytical framework departs “from a symmetrical attention to technology, society, and environment” and tries to advance the understanding of technology for the socio-ecological perspective in particular. By occupying the middle space between the social and the ecological spheres, technology is positioned in accordance to its mediating role in all human-environment relations. This stems from the recognition that we live in the realm of the artificial (Dilnot, 2009 p.184), whereby life is determined –and limited– by the “things” humans do and make, an idea otherwise captured in the concept of the Anthropocene (Steffen et al., 2011). By mediation, Ahlborg et al. (2019) refer to a “process of shaping, enabling, transforming, and conditioning the physical and symbolic interactions with our environment and other humans”. Moreover, technology is here understood to encompass methods, processes or devices that serve as means to extend human capacities and fulfill certain purposes (Ahlborg et al., 2019) and as such, represents a significant way in which physical and natural phenomena or resources are exploited for a particular functionality or goal –it is the result of human will.

This draws attention to what is often called the politics of technology (Winner, 2018), the ways in which it can enhance and transform human agency even beyond human capacities, often for the benefit of some and the misfortune of others. Technologies have a fundamental role in enabling or limiting certain power dynamics, and therefore, are value-laden and potentially biased as opposed to neutral and instrumental as they are often portrayed. Because technology is the result of human endeavour and design, the capacities that it extends to us humans can either improve or worsen the quality of our lives, potentially leading to alienation and destruction, or to liberation and environmental conservation (Ahlborg et al., 2019). In this way, technology has an ontological effect of shaping the conditions of our existence (Fry, 2014), extending or limiting it by reshaping the world and our practices within it (Verbeek, 2005), thereby demanding responsibility and attention to its wider impacts on the world across communities, time and space.

In summary, when addressing the complexity of the degree of change needed to face our current sustainability societal challenges, society, technology and the environment need to be addressed simultaneously. Any problem formulation, study, analysis or policy recommendation that would otherwise result from excluding either of such spheres would result superficial and limited (Ahlborg et al., 2019), failing to acknowledge the interdependent and complex dynamics that exist within our constructed and natural worlds. As Yorke et al. (2002) put it, “The sustainability transition requires an active redirection of devastating mismatches between societal dynamics and ecosystem dynamics.”.

Bridging language and models by design

The SES and STS communities have each adopted a specific language that relates to the analytical models that they adopt. Scholars working within STS adopt the multi-level perspective on transitions model –MLP (Geels, 2005), which identifies three levels: niche, socio-technical regime and socio-technical landscape. It stems from the understanding that the interactions between these socio-technical system levels are created and reshaped by the social actors that are part of the structures and the rules that they develop to orient their actions. From this perspective, a change from one socio-technical system to another is what represents a transition. Transitions are understood as multi-actor processes encompassing interactions between different social groups and as such, represent complex, non-linear processes that emerge from a diversity of dynamics occurring at different levels simultaneously –never displaying one single driver. These dynamics are socially constructed, and therefore change according to the varying interests and perceptions of its actors over time. The meso-level represents the socio-technical regime that is responsible for the stability of the existing socio-technical systems in place (Geels, 2005). On the other hand, the niche level represents the space for radical innovation and learning, which encompasses small initiatives that experiment with new technological and social configurations and where change is dynamic and fast.The landscape level refers to “exogenous” elements (politics, cultural and normative values, environmental and resource issues) where change is slower and beyond the direct influence of actors (Geels & Kemp, 2007). This model acknowledges that within a dynamic state of equilibrium, changes exist at all levels simultaneously, but not all result in immediate perceivable change. Cumulative, incremental change within the regime –what they refer to as a transformation– is what comes about as a result of a type of adaptation to pressures coming from the landscape level. This re-orientation of rules and actions (ie. change in visions, goals and regulations) is the result of negotiations, power struggles and new coalitions of actors, but does not imply a whole replacement of the existing system (Geels & Kemp, 2007). However, the cumulative adjustments performed by incumbent actors result in the redirection of the new development trajectory over time (through performance improvement). For this community, a transformation refers to a re-orientation while a transition implies a shift to a whole new trajectory. This shift is made possible by “windows of opportunity” as spaces for “creative destruction”, where innovations from the niches and the re-arrangement or collapse of some incumbent actors disrupt the existing development trajectories. Transitions are followed by periods of dynamic stability where the reproduction of existing rules and routines secure the new regime trajectory (Geels & Kemp, 2007).

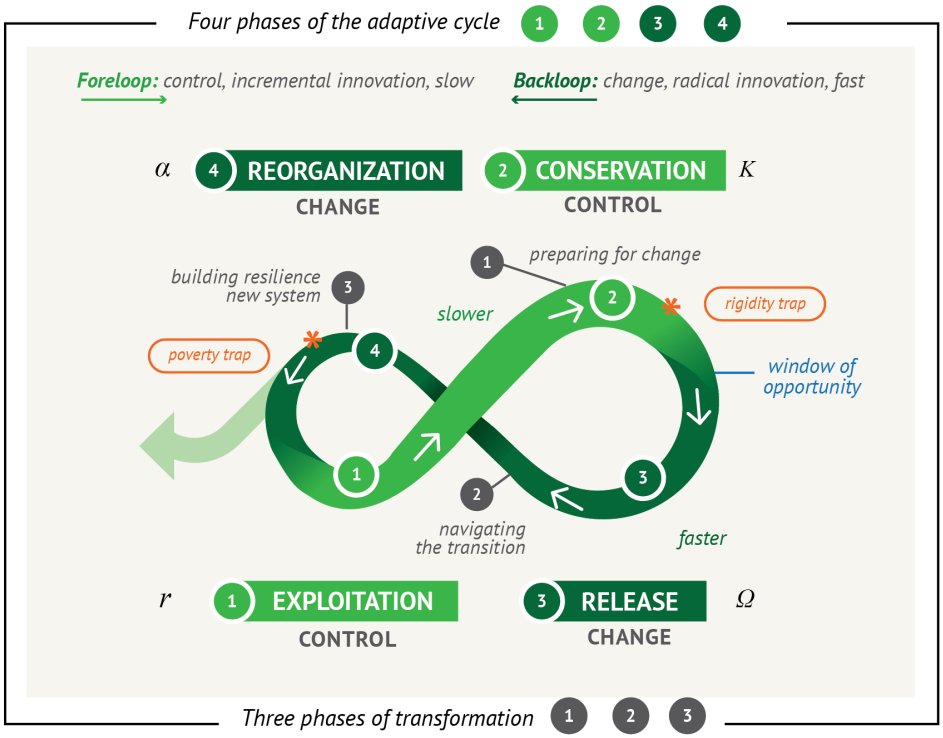

Figure 1: The complex adaptive cycle. Adapted from Holling & Gunderson (2002) and Briggs et al. (2010).

On the other hand, the SES community has embraced the Panarchy model (Holling & Gunderson, 2002) which explains how a set of nested complex adaptive systems (see loops in Figure 1) organise and interact over different spatio-temporal scales (Holling, 2001). Similar to the MLP model, this approach also understands the nested nature of processes and dynamics and the varying phases during which processes are enhanced or prevented. In the Panarchy model, the different adaptive cycles at play (loops) display four distinct phases of: growth and exploitation (r), conservation (K), collapse and release (Ω) and destruction and reorganization (α). From this view, two transitions exist in the two major phase changes: from growth to conservation (foreloop), and from collapse to reorganization (backloop). The change of state from one phase to the next is what they refer to as a transition (Holling, 2001). In this model, the most critical stage refers to what happens between the preparation for change and the period of building resilience of a new trajectory of development, that is, navigating the transition between destruction and re-organization (see backloop). In other words, what happens after the window of opportunity opens and radical innovation takes place, with a re-arrangement of actors and structures.

Given that the model recognises that there exist adaptive cycles that run across time and space simultaneously, the hierarchical-type model displaying different levels is only adopted as a way to visualize and highlight simultaneous processes that span across space (x axis) and time (y axis). Comparing both models shows that while the temporal dynamism and the relations across scales are highlighted in both models, the spatial dimension is less explicitly articulated in the MLP model. In natural systems, open systems boundaries and interdependence are more obvious and seen more holistically –ie. the Earth System as a whole. What is interesting to note between the two models is the relevance of experimentation and innovation and the tensions that exist between the creative destructive force and the resistance to change. In Holling's words, "the whole panarchy is both creative and conserving" (Holling & Gunderson, 2002, p.76). Similarly to how experimentation and

flexibility exists in niche innovations in the MLP model, the smaller and faster levels in the Panarchy model are the ones that invent and test, while the slower levels (foreloops) tend towards conservation and stabilization, which seek to conserve the memory of past experiments –where change is incremental. This is similarly equated to norms, structures and habits that over time get to become entrenched in a regime configuration in the MLP, while further applying to elements of the landscape, as in the case of larger socio-cultural aspects (social norms, politics) or environmental configurations (built infrastructure, natural resources). However, what's important to note in relation to the SES understanding of memory is that this stored knowledge or resources is crucial for informing the reorganization phase, that is, it becomes a sort of wisdom that enhances adaptive capacity.

In essence, both models agree that the lower, smallest levels that have the capacity for radical innovation and faster change, while the higher and larger levels –regimes– are more resistant to it. One of the key concepts that is important here is resilience, known as one of the key properties of SES and fundamental when enhancing adaptive capacity. Resilience represents the capacity of a system to remain within the same regime by absorbing or withstanding perturbations so that essential structures and functions can be maintained (Folke et al., 2010). While this property is more easily understood in the context of natural systems (preservation of ecosystem services for instance), it applies to social ones as well, and can be both positive or not, depending on the configuration that the system is resistant to. In the context of STS, this equals a state of lock-in. However, resilience also entails the degree to which a system can increase its capacity for learning, adaptation and self-organization (Carpenter & Folke, 2006) and may imply changing structures so as to preserve functions. This recognition has led the SES community to develop a comprehensive understanding of resilience as the capacity of a social-ecological system to "continually change and adapt while remaining within critical thresholds" (Folke et al., 2010). A few interesting aspects emerge from this understanding, especially considering social implications. First, and following Walker's recent articulation of resilience as about "learning how to change so as not to be changed" (Walker, 2020), is the important role of agency, where human's capacity to anticipate change and act to influence future pathways becomes critical. Secondly, it acknowledges the degree of uncertainty and unpredictability that exists within dynamic systems, whereby changes may happen abruptly –without disturbances– following processes of gradual change that may surpass threshold levels or tipping points (Milkoreit et al., 2018). In such a context, it becomes important to learn when a tipping point might be in proximity –by identifying early warning signals for instance (Scheffer et al., 2009), so that the preferable action (prevent or promote) can be taken before it is too late. New system configurations or states may result desirable or not, and restoration to previous states after a critical transition occurs (Scheffer et al., 2009) is complex and sometimes impossible.

To better understand the nuances of these change trajectories, this community has conceptualized Resilience Thinking, an approach characterized by seven principles and three key aspects: resilience, adaptability and transformability (Folke et al. 2010). Adaptability refers to the capacity to deal with and adjust to internal and external changes while staying within a regime, whereas transformability refers to the capacity to "cross thresholds into new development trajectories" or to create new ones altogether (Folke et al., 2010; Folke et al,. 2016). In essence, resilience means enhancing the adaptive capacity to be able to foster positive reconfigurations where different options and opportunities may stay open. This equals diversity and heterogeneity in biological terms but also in *knowledges*, institutions, networks, attitudes, skills and interests. Because one of the main barriers preventing transformations is often the high degree of resilience of certain societal patterns, transformability emerges as a key ingredient both for SES and STS (Folke et al., 2010; O'Brien, 2011). Beyond the language differences, both research communities have acknowledged that change often results from overcoming path dependence and crossing over critical thresholds to a state that can enable more flexible, collaborative forms of management and governance of resources. When navigating transitions to new development pathways or during periods of crisis, the roles of creativity and innovation are fundamental. This further means dealing with the status quo, engaging conflicting values and therefore addressing the role of agency and power relationships that may exist within elements and structure of relationships that try preserve a particular state. To radically break free or release lock-ins, collaboration and experimentation are elements highlighted

by both communities as strategic to enable shifts towards sustainability (Olsson et al., 2014)– either through niche innovations in STS or phases of creative reconfiguration in SES.

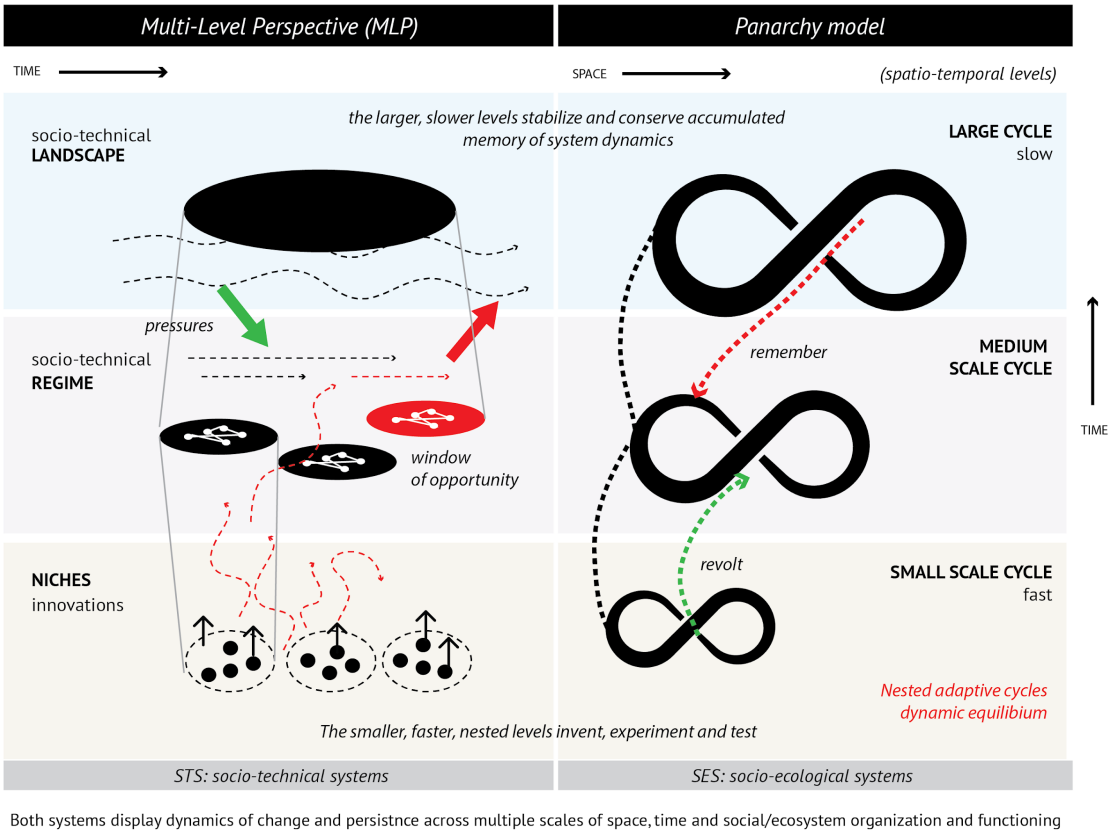

Figure 2: Visual comparison of the MLP and the Panarchy models. Adapted from Geels (2002), Geels & Kemp (2007) *and Holling & Gunderson (2002) by the author.*

As we learn from this brief introduction and graphics shown in Figure 2, there are various parallelisms between these models coming from transition theory and resilience theory beyond the choice of language (also see Ferguson et al., 2013 for a comparative table). Therefore, a better integration could help design studies that can form niches for experimenting and innovating with new configurations of social, technological and ecological systems in the face of increasing uncertainty and change (Olsson et al., 2014). While such collaboration between the different research fields represents a challenge if we take into account their different ontological and epistemological traditions, it is imperative to recognize that the integration of knowledges and ways of thinking and doing –across these fields and beyond–are fundamental if we are to imagine and enact fundamental, radical change that can support the wellbeing of humans within planetary boundaries. In this scenario, Transition Design (Irwin, 2015) has emerged as a design-led approach that positions itself as a space of research and practice with the capacity to synergize and synthesize plural views and discourses while enabling experimental and creative approaches to problems from a systemic perspective (Irwin, 2015b). While not being a prominent approach within transition and transformation discourses, it is argued to come to represent an important role as a mediator (Irwin, 2015b) between the otherwise known dualities of nature and culture, science and art, and in this case, STS and SES. The following section will articulate the main arguments for the integration of a design-led approach to societal transformations.

Changing Design and Designing Change

Design, as a discipline, is only a century old. It went from being a field in the service of enhancing and improving the production and consumption of goods (Margolin, 2002), towards a knowledge generation field that contained its own epistemology, praxiology and phenomenology (Cross, 1999). Nigel Cross refers to it as a third culture characterized by “designerly ways of knowing” (Cross, 1982), marking a clear differentiation from the well-established sciences and arts. This culture comes to represent technology and constitute itself as something distinct, representing a synthesis of knowledge and skills coming from the sciences and the humanities. This conception of design also aligns with what Herbert Simon refers to as the “sciences of the artificial” (Simon, 1988) when referring to objects and phenomena invented by humans (Margolin, 2002). Understanding this discipline as neither science nor art, helps us see that Design possesses its own purposes, values, measures and procedures (Owen, 1998) whereby the types of questions asked, and the knowledge produced, are very different to those of the other disciplines. Still by synthesizing knowledge from them, it represents a truly integrative and yet pragmatic field that can simultaneously address understanding, communication and action (Buchanan, 1992).

While design has the potential to address the so so called wicked or ill-defined problems, as opposed to the “tame problems” typically addressed by the sciences, traditional design has also been criticized for being implicated in the development of our current unsustainable lifestyles by shaping products, habits, environments and cultures that have negative societal and environmental impacts (Papanek, 1985). However, that is the case for the more traditional or insular types of design practice, whereby design acts mostly as form-giver or focused on addressing comercial –consumption– needs (Irwin, 2015). However, over the past decades, the field of design has moved on to engage in practices with far-reaching impacts moving towards designing product-services systems, and more recently, to fully engage in addressing more systemic and complex societal challenges (Ceschin & Gaziulusoy 2019; Irwin, 2015; Jones, 2017; Jonas & Anshelm, 2015). Transition Design, as one of the emerging approaches, explicitly acknowledges the intractability of our current challenges and their social roots through its focus on wicked problems (Irwin, 2015). These are defined as a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (as quoted in Buchanan, 1992). The ill nature is what differentiates these problems as indefinable and inseparable and hence, not leading to the finding a single solution though a linear thinking process. Any proposed solution can be the start of a new problem so it becomes essential to not rush into excluding any aspect or dynamics that are part of the systems that we aim to change. Following the argumentation presented above, it means not neglecting technology or the biosphere.

Another aspect that characterises *designerly* knowledge, is that it broadly adopts solution-focussing strategies with the aim of advancing towards action through abductive, productive thinking and the support of non-verbal media for visualization, experimentation, communication and materialization (Cross, 1982). This type of “thinking-through-action” is thus generative, tangible, explorative and future-focused. It is mostly concerned with imagining possibilities, not just what *ought* to be but what *may* be –imagining and planning for that which does not yet exist (Cross, 1982). In this sense, design has been popularized to be apt to navigate uncertainty because of the indeterminacy of the type of problems it addressed and its capacity to pragmatically invent and develop working hypotheses that can help advance towards the problem resolution even when there is a lack of information (Cross, 1982). This often comes about through exploring different framings of the problem, and through extensive experimentation and testing in which problem and solution co-evolve (Dorst & Cross, 2001). Designers rely on different sources of knowledge and wisdom (intuition, scientific and tacit knowledge, lay and indigenous knowledge, etc.) that is synthesized, materialized and tinkered-with, in an iterative, flexible process. These designerly capabilities became popularized outside of the field as “design thinking” (Brown, 2008), which has helped communicate the potential application of design in enabling innovation, collaboration and trigger rapid change mostly within business and government settings (Cooper et al., 2009).

With this popularity, designers have also started engaging in new arenas and research collaborations (Muratovski, 2015) on a more symmetrical level, and not just for visualizing or communicating the final outcomes of a project. One of the aspects that design has been advancing is its transdisciplinary and participatory-focus (Buchanan, 1992; Brown et al., 2010), by not only engaging with diverse fields of knowledge but also multiple actors and their perspectives and worldviews (Escobar, 2018). Through these synergies, it is able to propose new questions and discover possibilities otherwise unseen. Design is valued for its capacity to "bring things together" (Duclos, 2010), particularly when transferring and translating knowledge during the production of new knowledge and artefacts. An analysis that considers the sociology of technology is useful when understanding that the material outcomes and the "socio technical assemblages" that are shaped through design (Duclos, 2010; Latour, 2019), become active shapers of reality and help constitute whole lifeworlds. By dealing with artificiality and technology both materially and symbolically, design is not only purposely mediating relations but also shaping and being shaped through its unfolding (Willis, 2006). This has evolved in deeper understandings of the role of design in enabling or limiting future possibilities (Fry 2008) and in the recognition that our lives are inherently mediated by design and its ever pervasive existence (Margolin, 2002). This has led many scholars to state that because the human experience of the natural world is always mediated through design (Papanek, 1985; Margolin, 2002), it could be said that we exist in strictly artificial and designed worlds (Margolin, 2002; Simon, 1988). The implication of this is that the act of designing carries a deep responsibility and has an important role to play in enabling –and limiting– the possibility of life flourishing on Earth (Fry, 2008).

In alignment with this, emerging design-led approaches have explicitly focused on tackling system-level challenges and working towards the active reconfiguration of transition processes (Irwin, 2015) to help realize socio-technical systems transformations. Designing for Sustainability Transitions (Ceschin & Gaziulusoy 2019) integrate different approaches that help conceptualize, visualize, imagine and operationalize a diversity of experiments to co-create and materialize transition pathways. Such interventions may seek to foster changes in values, technologies, social practices, lifestyles, infrastructures and reshape the interactions between socio-technical and socio-ecological systems (Ceschin & Gaziulusoy, 2019). Approaches such as Transition Design (Irwin, 2015), Transformation Design (Jonas et al., 2015) and Design for Resilience (Baek et al., 2015) try to support collective efforts for re-imagining and enacting desirable futures and foster innovation initiatives across spatio-temporal levels and scales, with a focus on enhancing quality of life. From this systemic scope of action, Ceschin and Gaziulusoy (2019) have explicitly recognized that Design needs to shift its focus to embrace a socio-technical-ecological systems framing –STES. This means acknowledging the key role of technology and the artificial, but also bringing back its attention to the biosphere and the future of all life on Earth. However, said systemic approaches have not engaged fully with the deep understanding of resilience advocated by the SES community. In spite of this, there is potential for the intersection of design and resilience thinking, when we understand design's capacity to foster transformability.The next section will articulate overlaps and correlations as a way to offer insights into the potential contribution of Design within this approach.

Translating Design's role in Resilience Thinking for sustainable change

A series of definitions and considerations have been laid out in order to construct an argument for the relevance of the integration of design as pertaining to the realm of the artificial –the layer of technology or artifice as mediator and shaper of human-environment interactions. In addition, design has been introduced as a third culture beyond the sciences and the humanities –as a science of the artificial. But, while the SES community has explicitly acknowledged the need for the integration of the arts and the sciences, it has excluded Design. The general low participation of designers within SES communities (as is experienced by the author who belongs to a SES community of practice) suggests that there is a need to better articulate and communicate its potential role in helping enable sustainability transformations. At the same time, while design has engaged with the concept of resilience (see Baek et al., 2015), it has not been articulated beyond a socio-technical sphere,

therefore often excluding ecosystem-related insights or environmental aspects. Furthermore, there is still a lack of clarity and deeper understanding of the scope, breadth and nuances behind the concept of resilience as it has been developed in the field of SES more recently. To bridge this gap, the seven core principles that constitute the Resilience Thinking approach are outlined in the following table with correlations to capabilities, methods and tools that exist within design. This seeks to offer a tool to help bridge the communication and language gap between Design, SES and STS.

Resilience Thinking principles and actions		*Correlation with design skills & methods (esp. TD)*	
Maintain diversity and redundancy 1	***Promote diversity of components, species, actors, views, knowledge. Enable compensation of functions in case of failures.***	Integration of knowledges and tools, transdisciplinarity, divergence and idea generation, testing, iteration. Collaboration.	Plurality, tacit knowledge, indigenous wisdom. Multiple skills, capacity building. Learning by doing. Generative. Facilitate participatory processes
Manage connectivity 2	***Balance too few vs. too many connections. Disturbances spread fast in over-connected systems.***	Systems thinking and visualization. Communication & information flows. Synthesis, understanding.	System mapping. Foster connectedness /networking. Wicked problems focus.. Understand needs & manage differences.
Manage slow variables and feedbacks 3	***Understand feedback loops (positive and negative) and their potentially amplifying consequences. Slow changes can add up to suddenly trigger rapid undesirable/unrecoverable changes.***	Problem reframing. Stakeholder involvement. Large spatio-temporal scales. Focus on processes. Prototype and test. Observation.	Long-term involvement. Observation, balance action vs. non-action. Manage surprise and uncertainty. Anticipate Intervention effects. Imagine, prototype.
Foster complex adaptive systems thinking 4	***Constant changes occur at different levels; seek to incorporate multiple perspectives. Accept uncertainty and unpredictability.***	Multi-level analysis approaches. Working hypothesis and iterations. Creativity, imagination and visioning. Anticipation.	Adopt various system-level tools. Stakeholder mapping. Creative exploration / prototyping. Learn-by-doing. Generate visions, stories, narratives. Backcasting. Experiential futures.
Encourage learning and experimentation 5	***Systems are in constant development. This requires evaluation, reflection and new learning. Experimentation and collaboration foster faster learning and synthesis.***	Reflexivity, learning by doing. Knowledge synthesis for innovation. Hands-on experimentation. Co-design.Prefiguration.	Experimental spaces & labs Knowledge communication. Visualizations. Collaborative practices & facilitation. Learning experiences & tools. Generative workshops.
Broaden participation 6	***Participation fosters shared understanding, trust building and other capacities for action.***	Participatory spaces, processes and methods. Playfulness. Team-building and integration. Plurality of views.	Stakeholder involvement. Participatory design methods. Manage expectations. Openness, Empathy. Facilitate communication/ translation.
Promote polycentric governance systems 7	***Distribute governance across networks to allow for flexible solutions, self-organizations and more effective application in specific settings. Involve and negotiate trade-offs among diverse stakeholders.***	Social innovation and facilitation. Capacity building. Experimentation and adaptability (iterations). Creating connections. Communication, visualization and dissemination.	Theories of change. Understand dynamics & conflict. Support decision-making. Build capacities, autonomy. Foster cosmopolitan localism. Facilitate information flows.

Right column: specific approaches used in Transition Design

Table 1: Resilience Principles goals, actions and their correlation in Design.

The table proposed here (Table 1) attempts to synthesize key elements drawn from Design literature and which relate to a diverse set of attitudes (Rawsthorn, 2018), methods, and tools that are particularly suited to face the challenges of managing resilience and fostering large systems transformations in their relation to the seven core principles (Anshelm et al., 2016). The literature portrays design as particularly apt to: face uncertainty and surprise, integrate different knowledges and disciplines, contribute to translation and communication, facilitate collaboration and innovation across different actors, aid in the visualization and reframing of complex, ill-defined problems, explore, test and experiment with solutions and interventions, help speculate, imagine and develop desirable visions for sustainable futures that can help improve governance and aid decision-making processes while effectively changing the values, practices, meanings and products that constitute our reality (Gerber & Carroll, 2012; Paton & Dorst, 201; Kimbell, 2015; Muratovski, 2015; Brandt et al., 2008; Binder & Brandt, 2008; Ceschin & Gaziulusoy 2019). Understanding that the locus and focus of all design activity is essentially people (Dilnot, 2009), all of these features particularly pertain and are experienced in the context of people's everyday lives. The following section will thus articulate the potential intersections between transition theory, resilience theory and Transition Design through its potential binding role.

Materializing synergies: design, resilience and transitions

Transition Design has been proposed as an approach that while adopting a holistic approach based on living systems theory and integrating diverse transition discourses, has mostly focused on a socio-technical systems framing (Irwin, 2015b). While this is in accordance with Design's realm of action in relation to "the artificial", extending its scope to include resilience thinking and insights from the SES perspective would bring further tools and approaches to inform more ecologically-aware interventions while further exploiting its capacity for supporting transformability. The recognition that managing resilience through a Resilience Thinking lens can be supported and facilitated through design, opens a space of opportunity and collaborations across these three areas (see Figure 3). Design's role in enabling sustainability transitions integrating a Resilience Thinking approach would focus on two main aspects: (a) the understanding of the mutual connections between social, economic, political, technological and natural systems when addressing complex, entrenched problems, as well as (b) pursuing the goal of improvement of the quality of life, not just for humans, but also for all living beings (Irwin, 2015). Integrating Resilience thinking and SES into framings wich focus on STS, such as transitions management, or transition design could bring new perspectives, tools and approaches to inform more holistic understandings of transformation, restituting the interplay between the social and technological (including the man-made world: technology or the artifice) and the biosphere (the natural layer that supports life on Earth). Taking a design-led approach means promoting a focus on "the relations between things and persons and things and nature" Dilnot (2009, p. 183), the focus of what design *designs*. In alignment with this, Transition Design particularly advocates focusing on the reconception of entire lifestyles which can exist in harmony with both the natural and the artificial worlds and structures (Irwin et al., 2017; Kossoff et al., 2015). Lifestyles, the practices, habits and artefacts that shape them represent the area that cuts across all systems levels –from human cells, to whole societies. Whether focusing on socio-technical or ecological systems, human daily activities not only determine but also emerge from the dynamics that exist across levels, be that politics, economics, culture, the built environment, technology, social norms, natural resources, governance models and policy, etc. People, their lives, and their "worlds" are the very core of design, and in that, design's focus is on "seizing and realizing the potential of situations to be transformed" (Dilnot, 2009, p. 184). The creativity of design is brought forth for the visualization and materialization of new possibilities, and through that, to prefigure new life and world configurations. Because of this, the realm of everyday life represents a potential space for improved engagement, understanding and action –promoting governance and enhancing the role of agency that people have in imagining and actively shaping their preferred futures. In alignment with this, the main argument here is that Transition Design offers the possibility to creatively experiment and create novel ways of engaging and developing the wisdom –as in knowledges, skills and judgement– that is required to navigate our current transitions, and hence, ensure to keep future possibilities for humanity open.

As a way to more succinctly understand these overlaps, the figure offered here (Figure 3) seeks to visualize the intersections and potentialities articulated throughout this piece. It aims to highlight the overlaps and potentialities afforded by Transition Design and its integration with transition theory and resilience theory, by adopting an STES framing. This graphic seeks to represent an initial tool that outlines a starting point for motivating more exhaustive theoretical articulations and motivate examples in practice that may come about through interdisciplinary collaboration across these three approaches together with the integration of other knowledge systems and ways of knowing, fully embracing a focus on plurality and diversity as it exists in the real experiences of people as they go about their daily lives in their particular contexts.

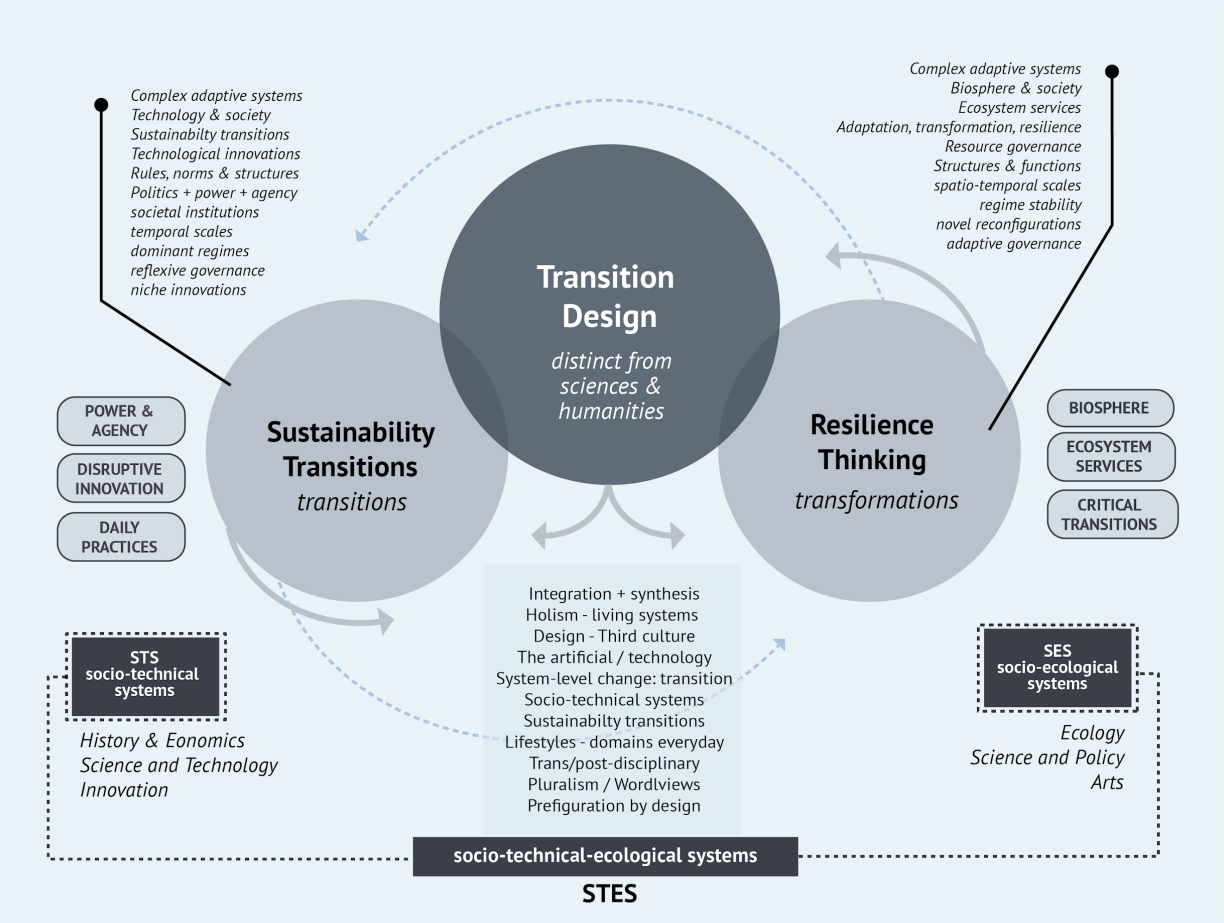

Figure 3: Integration of a design-led perspective to foster transitions and a transformability capacity: Transition Design as a mediator. Developed by the author.

Concluding remarks

Responding to a need of expanding the understanding of the role of technology and the potential of the integration of design within research groups working towards sustainability transformations and change, a conceptual model has been proposed that highlights the spaces and potential contributions of integrating design capabilities into inter and transdisciplinary teams working for STES transformations towards sustainability. To further exemplify and open this framework to its expansion and practical adoption, a series of visual models have been proposed. These seek to not only communicate the potential of a design-led approach to sustainability transitions but also to foster the adoption of a more integrative perspective while bridging the gaps and differences in language and systems framings. The materialization of these conceptual models into diagrams with an integrative

and synthetic approach driven by design make these perspectives more tangible, bringing them into a new life. This way, it hopes to facilitate dialogues and collaborations across individuals from otherwise different or unconnected spheres. By highlighting the role of design in mediating and facilitating human-environment interactions, particularly aided by its capacities for visualization, materialization, experimentation and innovation, has shown that Design is particularly relevant when fostering a capacity for transformability across scales. This means a way to enhance positive resilience while creatively exploring what the possibilities of the artificial *are* for us (Dilnot, 2009, p.184). After all, "good designs become our habitats and habits that can determine future pathways for our societies. All this implies that design can play a more central role in the discourse of transition" (Irwin, 2015b), and in responding to the call for radical and fundamental societal change. At the same time, by stressing the importance of understanding and managing resilience, both in ecosystems and societies, this aligns with the overarching goal of fostering a sustainability transition, one which will only come about if we improve our adaptive capacity to learn and respond to change (Yorke, 2002). It is hoped that the potential space for more design integration and collaboration has been clarified, especially to communities of scholars not very literate in this field.

References

Ahlborg, H., Ruiz-Mercado, I., Molander, S., & Masera, O. (2019). Bringing Technology into Social-Ecological Systems Research—Motivations for a Socio-Technical-Ecological Systems Approach. *Sustainability*, *11*(7), 2009–2009.

Anshelm, K. von, Jonas, W., & Zerwas, S. (Eds.). (2016). *Transformation design: Perspectives on a new design attitude*. Birkhäuser Verlag GmbH.

Baek, J. S. S., Meroni, A., Manzini, E., & Meroni, A. M., Ezio. (2015). A socio-technical approach to design for community resilience: A framework for analysis and design goal forming. *Design Studies.*, *40*, 60–60. https://doi.org/10.1016/j.destud.2015.06.004

Binder, T., & Brandt, E. (2008). The Design:Lab as platform in participatory design research. *CoDesign*, *4*(2), 115–129. https://doi.org/10.1080/15710880802117113

Brandt, E., Messeter, J., & Binder, T. (2008). Formatting design dialogues – games and participation. *CoDesign*, *4*(1), 51–64. https://doi.org/10.1080/15710880801905724

Biggs, R., Westley, F., & Carpenter, S. (2010). Navigating the Back Loop: Fostering Social Innovation and Transformation in Ecosystem Management. *Ecology and Society*, *15*(2). https://doi.org/10.5751/ES-03411-150209

Brown, V. A., Harris, J. A., & Russell, J. Y. (2010). *Tackling wicked problems through the transdisciplinary imagination*. Earthscan.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues*, *8*(2), 5–21.

Carpenter, S. R., & Folke, C. (2006). Ecology for transformation. *Trends in Ecology and Evolution*, *21*(6), 309–315. https://doi.org/10.1016/j.tree.2006.02.007

Ceschin, F., & Gaziulusoy, İ. (2019). *Design for Sustainability*. Routledge. https://doi.org/10.4324/9780429456510

Cooper, R, Junginger, S. & Lockwood, T. (2009). Design Thinking and Design Management: A research and Practice Perspective. In *Design Thinking: Integrating Innovation, Customer Experience, and Brand Value*. 3rd ed. Allworth Press

Cross, N. (1982). *Designerly ways of knowing* (Vol. 3). https://doi.org/10.1016/0142-694X(82)90040-0

Cross, N. (1999). Design Research: A Disciplined Conversation. *Design Issues*, *15*(2), 5–10. https://doi.org/10.2307/1511837

Dilnot, C. (2009). Ethics in Design: 10 Questions. In Brody, D. Eric., & Clark, Hazel. (Eds.), *Design studies: A reader* (pp. 180-190). Berg.

Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problem–solution. *Design Studies*, *22*(5), 425–437.

Duclos Lindstrøm, M. (2010). Deep Translations. In *Design Research: Synergies from Interdisciplinary Perspectives*, edited by Simonsen, Jesper, Jørgen Ole Bærenholdt, Monika Büscher, and John Damm Scheuer (pp.109-122). Routledge.

Escobar, A. (2018). *Designs for the pluriverse: Radical interdependence, autonomy, and the making of worlds*. Duke University Press.

Ferguson, B. C., Brown, R. R., & Deletic, A. (2013). A diagnostic procedure for transformative change based on transitions, resilience, and institutional thinking. *Ecology and Society*, *18*(4).

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, *21*(3). https://doi.org/10.5751/ES-08748-210341

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Ecology and Society*, *15*(4), art20–art20. https://doi.org/10.5751/ES-03610-150420

Fry, T. (2014). The Origin of the Work of Design: Thoughts based on a Reading of Martin Heidegger's "The Origin of the Work of Art". *Design Philosophy Papers*, *12*(1), 11–22. https://doi.org/10.2752/144871314X14012672861973

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technology Analysis & Strategic Management*, *17*(4), 445–476.

Geels, F. W., & Kemp, R. (2007). Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. *Technology in Society*, *29*(4), 441–455. https://doi.org/10.1016/j.techsoc.2007.08.009

Gerber, E., & Carroll, M. (2012). The psychological experience of prototyping. *Design Studies*, *33*(1), 64–84. https://doi.org/10.1016/j.destud.2011.06.005

Holling, C. S. (2001). Understanding the complexity of economic, ecological, and social systems. *Ecosystems*, *4*(5), 390–405. https://doi.org/10.1007/s10021-001-0101-5

Holling, C. S., & Gunderson, L. H. (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.

Hölscher, K., Wittmayer, J. M., & Loorbach, D. (2018). Transition versus transformation: What's the difference? *Environmental Innovation and Societal Transitions*, *27*(April 2017), 1–3. https://doi.org/10.1016/j.eist.2017.10.007

Irwin, T. (2015). Transition Design: A Proposal for a New Area of Design Practice, Study, and Research. *Design and Culture*, *7*(2), 229–246. https://doi.org/10.1080/17547075.2015.1051829

Irwin, T., Kossoff, G., & Tonkinwise, C. (2015b). Transition Design: An Educational Framework for Advancing the Study and Design of Sustainable Transitions, paper for the 6th International Sustainability Transitions Conference. *University of Sussex, UK*.

Irwin, T., Kossoff, G., Tonkinwise, C., Irwin, T., Kossoff, G., & Tonkinwise, C. (2017). Transition Design Provocation Transition Design Provocation *. *Design Philosophy Papers*, *13*(1), 3–11. https://doi.org/10.1080/14487136.2015.1085688

Jonas, W., Zerwas, S., & Anshelm, K. von. (2015). Introduction. In *Introduction* (pp. 9–22). Birkhäuser. https://doi.org/10.1515/9783035606539-002

Jonas, W., Zerwas, S., & Von Anshelm, K. (2015). *Transformation Design: Perspectives on a new design attitude*. Birkhäuser.

Jones, P. (2017). The Systemic Turn: Leverage for World Changing. *She Ji*, *3*(3). https://doi.org/10.1016/j.sheji.2017.11.001

Jones, P. H. (2014). Systemic Design Principles for Complex Social Systems. In G. S. Metcalf (Ed.), *Social Systems and Design* (pp. 91–128). Springer Japan. https://doi.org/10.1007/978-4-431-54478-4_4

Kimbell, L. (2015). Rethinking Design Thinking: Part I. *Design and Culture*, *3*(December), 285–306. https://doi.org/10.2752/175470811X13071166525216

Kossoff, G., Tonkinwise, C., & Irwin, T. (2015). *Transition design: The importance of everyday life and lifestyles as a leverage point for sustainability transitions*. 6th International Sustainability Transitions Conference.

Krippendorff, K. (2011). Principles of Design and a Trajectory of Artificiality. *Journal of Product Innovation Management*, *28*(3), 411–418. https://doi.org/10.1111/j.1540-5885.2011.00814.x

Latour, Bruno. (2019). A Cautious Prometheus? A Few Steps Toward a Philosophy of Design, In *The Design Philosophy Reader* (pp. 18-21). Bloomsbury Visual Arts.

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. *Annual Review of Environment and Resources*, *42*(1), 599–626. https://doi.org/10.1146/annurev-environ-102014-021340

Margolin, V. (2002). *The politics of the artificial: Essays on design and design studies*. University of Chicago press.

Margolin, V. (2015). Human Systems Design: A New Direction for Practice. In *Transformation Design* (pp. 149–165). Birkhäuser. https://doi.org/10.1515/9783035606539-012

Milkoreit, M., Hodbod, J., Baggio, J., Benessaiah, K., Calderón-Contreras, R., Donges, J. F., Mathias, J. D., Rocha, J. C., Schoon, M., & Werners, S. E. (2018). Defining tipping points for social-ecological systems scholarship—An interdisciplinary literature review. *Environmental Research Letters*, *13*(3). https://doi.org/10.1088/1748-9326/aaaa75

Muratovski, G. (2015). *Research for designers: A guide to methods and practice*. Sage.

O'Brien, K. (2011). Global environmental change II: From adaptation to deliberate transformation. *Progress in Human Geography*, *36*(5), 667–676. https://doi.org/10.1177/0309132511425767

Olsson, P., Galaz, V., & Boonstra, W. J. (2014). Sustainability transformations: A resilience perspective. *Ecology and Society*, *19*(4). https://doi.org/10.5751/ES-06799-190401

Owen, C. L. (1998). Design research: Building the knowledge base. *Design Studies*, *19*(1), 9–20.

Papanek, V. J. (1985). *Design for the real world: Human ecology and social change* (2nd ed., c). Academy Chicago.

Paton, B., & Dorst, K. (2011). Briefing and reframing: A situated practice. *Design Studies*, *32*(6), 573–587. https://doi.org/10.1016/j.destud.2011.07.002

Preiser, R., Biggs, R., De Vos, A., & Folke, C. (2018). Social-ecological systems as complex adaptive systems: Organizing principles for advancing research methods and approaches. *Ecology and Society*, *23*(4). https://doi.org/10.5751/ES-10558-230446

Raudsepp-Hearne, C., Peterson, G. D., Bennett, E. M., Biggs, R., Norström, A. V., Pereira, L., Vervoort, J., Iwaniec, D. M., McPhearson, T., Olsson, P., Hichert, T., Falardeau, M., & Aceituno, A. J. (2019). Seeds of good anthropocenes: Developing sustainability scenarios for Northern Europe. *Sustainability Science*. https://doi.org/10.1007/s11625-019-00714-8

Rawsthorn, Alice. (2018). *Design as an attitude*. JRP Ringier.

Rittel, H., & Webber, M. (1984). *Planning problems are wicked problems. N. Cross (Ed.). Developments in Design Methodology (pp. 135-144)*.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., & Schellnhuber, H. J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14*(2).

Scheffer, M., Bascompte, J., Brock, W. A., Brovkin, V., Carpenter, S. R., Dakos, V., Held, H., Van Nes, E. H., Rietkerk, M., & Sugihara, G. (2009). Early-warning signals for critical transitions. *Nature*, *461*(7260), 53.

Simon, H. A. (1988). The science of design: Creating the artificial. *Design Issues*, 67–82.

Sommer, B., & Welzer, H. (2015). Transformation Design: A Social-Ecological Perspective. In *Transformation Design: A Social-Ecological Perspective* (pp. 188–201). Birkhäuser. https://doi.org/10.1515/9783035606539-015

Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., Crumley, C., Crutzen, P., Folke, C., Gordon, L., Molina, M., Ramanathan, V., Rockström, J., Scheffer, M., Schellnhuber, H. J., & Svedin, U. (2011). The Anthropocene: From Global Change to Planetary Stewardship. *AMBIO*, *40*(7), 739. https://doi.org/10.1007/s13280-011-0185-x

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., Brinsden, H., Calvillo, A., De Schutter, O., Devarajan, R., Ezzati, M., Friel, S., Goenka, S., Hammond, R. A., Hastings, G., Hawkes, C., Herrero, M., Hovmand, P. S., Howden, M., … Dietz, W. H. (2019). *The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report* (pp. 791–846). Elsevier. https://doi.org/10.1016/S0140-6736(18)32822-8

Verbeek, P.-P. (2005). *What things do: Philosophical reflections on technology, agency, and design*. Penn State Press.

Walker, B. H. (2020). Resilience: What it is and is not. *Ecology and Society*, *25*(2). https://doi.org/10.5751/ES-11647-250211

Willis, Anne-Marie. (2006). Ontological Designing. *Design Philosophy Papers* 4 (2): 69–92. https://doi.org/10.2752/144871306X13966268131514.

Winner, L. (2018). Do Artifacts Have Politics? *Computer Ethics*, *109*(1), 177–192. https://doi.org/10.4324/9781315259697-21

Yorke, R. (2002). Toward an Integrative Synthesis In Holling, C. S., & Gunderson, L. H. (Ed.), *Panarchy: Understanding transformations in human and natural systems* (pp. 419-438). Washington, DC: Island Press.