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SPECIAL FEATURE: ORIGINAL ARTICLE

Theoretical traditions in social values for sustainability

Values in transformational sustainability science: four perspectives for change

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Abstract
Despite the normative nature of sustainability, values and their role in sustainability transformations are often discussed in vague terms, and when concrete conceptualizations exist, they widely differ across fields of application. To provide guidance for navigating the complexity arising from the various conceptualizations and operationalization of values, here, we differentiate four general perspectives of how and where values are important for transformation related sustainability science. The first perspective, surfacing implicit values, revolves around critical reflection on normative assumptions in scientific practices. Sustainability transformations concern fundamental ethical questions and are unavoidably influenced by assumptions sustainability scientists hold in their interactions with society. The second perspective, negotiating values, is related to the values held by different actors in group decision processes. Developing and implementing solution options to sustainability problems requires multiple values to be accounted for in order to increase civic participation and social legitimacy. The third perspective, eliciting values, focuses on the ascription of values to particular objects or choices related to specific sustainability challenges, for example, valuations of nature. The fourth perspective, transforming through values, highlights the dynamic nature and transformational potential of values. Value change is complex but possible, and may generate systemic shifts in patterns of human behaviours. Explicit recognition of these four interconnected values perspectives can help sustainability scientists to: (1) move beyond general discussions implying that values matter; (2) gain an awareness of the positionality of one's own values perspective when undertaking values related sustainability research; and (3) reflect on the operationalizations of values in different contexts.

Keywords Sustainability transformation · Transdisciplinarity · Value negotiation · Eliciting values · Value shift

Introduction

At its core, sustainability is a normative, value-based concept. It is increasingly recognised that science dealing with sustainability transformations has to engage with normative and values related issues (Seidl et al. 2013). However, values and their role are often discussed in elusive terms within sustainability research. Given the interdisciplinary nature of sustainability science, even when clear conceptualizations exist, these differ widely across fields of application. There is a diverse range of theoretical conceptualizations (for a comprehensive overview, see Rawluk et al. 2019) related to values: individual, shared, or social values; economic values; environmental and human values; held and assigned values; intrinsic, instrumental or relational values; and transcendental and contextual values (Dietz et al. 2005; Kenter et al. 2015; Tadaki et al. 2017). This diversity reflects not just different philosophical and scientific traditions, but also the multiple ways in which the notion of value shape and constrain our understanding of, and action, in the world. However, these diverse understandings of value seem to exist in relative isolation from each other. In contrast to the theoretical richness, there is less scientific discussion on how values should, or could, be operationalized in relation with

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transformation-oriented sustainability science. Partly, this lack of discussion may be because 'values' are a challenging research object, given their multifaceted nature and the difficulties in defining, eliciting, or measuring values in the context of transformational change.

How can the necessarily value-laden field of sustainability science navigate the diversity of perspectives to conceptualising and operationalizing values in relation with transformational change? Here, we suggest that a useful starting point is to consider the ways values are studied or operationalized in transformational sustainability science. To this end, we organise this paper around four perspectives of how and where values are engaged within transformation-oriented sustainability science, where by 'perspective', we mean a tradition of shared enquiry and practice. Each perspective is bounded by shared broad conceptualizations of, and research approaches to, values in relation with transformational change. In describing such perspectives, our intention is not to provide a definitive typology or framework for considering values in sustainability science. Rather, we wish to surface the multiple roles values are thought of as having, and to encourage a more systematic and explicit consideration of their interactions and importance in investigating and seeking transformational change towards sustainability.

As previously noted, a large number of different values typologies exist in the academic literature. Here, we focus on transcendental and contextual values, as they seem particularly apt in the context of how values are engaged within sustainability science. We acknowledge that this provides a particular lens through which to view the four values perspectives that we develop, but note that this is a necessary constraint of any discussion of values in sustainability science. Following Kenter et al. (2015), we differentiate between: (1) transcendental values—referred to by Brown (1984) as held, first-order preferences—that transcend specific situations and guide selection or evaluation of behaviour and events and (2) contextual values—ascribed, second-order preferences—that relate to the worth or importance of a particular object, choice, or state of the world. Unless mentioned otherwise, in this paper, we focus on transcendental values defined as "concepts […] that pertain to desirable end states or behaviours, transcend specific situations, guide selection, or evaluation of behaviour and events, and are ordered by relative importance" (Schwartz 1992:4; 2012), in agreement with the *Transcendental values* concept in the overview of value concepts provided by Rawluk et al. (2019).

Within the broad class of transcendental values, different typologies exist, each with different dimensions to discriminate between values. For example, in his seminal work, Schwartz (2012) distinguishes between ten motivational types of values recognised across cultures. Alternative typologies differentiate between values operating at various levels: from individual to collective (e.g., social and cultural values). This paper focuses on social values, rather than individual values, where social values refer to the outcome of social processes of deliberation about transcendental values (see also Kenter et al. 2015; Rawluk et al. 2019). We make this distinction between individual and social values, because the practice of sustainability and sustainability science are inherently social processes involving the negotiation of values among different stakeholders, shaped by institutional (including institutions of science) norms. We also make a distinction between social and cultural values; while both operate at supra-individual level, cultural values are less abstract than social values (Rawluk et al. 2019) and more dependent on the local context (Van Riper et al. 2019) rather than on the outcomes of deliberative social processes.

The four values perspectives in sustainability science we describe in more detail below are:

The surfacing implicit values perspective, which revolves around the often unexpressed and unacknowledged values that sustainability science embeds within transformational research. This perspective questions how such underpinning transcendental values shape and constrain insights and solution opportunity spaces in sustainability science. The negotiating values perspective relates to the plurality of transcendental and contextual social values that interact in transformational processes. This perspective asks questions related to whose values count, and how such values are accommodated in, and shape, the outcomes of participatory and group decision processes. The eliciting values perspective looks at the explicit articulation of transcendental values as revealed in contextual value judgments such as ascribing values to particular choices, objects, or actions related to specific sustainability challenges and potential changes in the state of the world. This perspective asks questions regarding which values are ascribed, and how these values are elicited to inform decision-making and management processes. The transforming through values perspective engages with questions related to values as intervention points for transformational changes towards sustainability, arguing that the latter require systemic shifts in deeply held values (Table 1, Fig. 1). For each of these perspectives, we focus on: (1) a general description of the perspective and the way in which values are engaged with; (2) the relevance of the perspective for sustainability science; (3) the identification and importance of under-considered aspects of the perspective; and (4) a practical suggestion for how each perspective could be considered in sustainability science. To illustrate the perspectives, especially point (4) above, we present examples based on a single research project called 'Leverage Points for Sustainability Transformation' (Abson et al. 2017). The project is a transdisciplinary endeavour aiming to explore system characteristics, where interventions can lead to transformational as opposed to incremental changes in the

Table 1 Summary of the four proposed values perspectives for sustainability transformation

	Main focus of operationalization	Main question (How?)	Context of operationalization (Where?)	Examples
Surfacing implicit values	Surfacing implicit values	How do underpinning values shape insights and solution opportunity spaces in sustainability science?	Research models and practices	Transdisciplinarity
Negotiating values	Navigating the plurality of values	Whose values count, and how do such values shape the outcomes of participatory processes?	Facilitating group decision-making and policy processes	Participatory processes involving multiple actors
Eliciting values	Eliciting values ascribed to particular objects or states of the world	Which values, and how values are elicited to inform decision-making processes?	Informing decision-making and management processes	Ascribing values processes (valuation exercises)
Transforming through values	Leveraging values for changing states of the world	How can values serve as intervention points for facilitating transformational changes?	Transformational processes	Systemic value shift

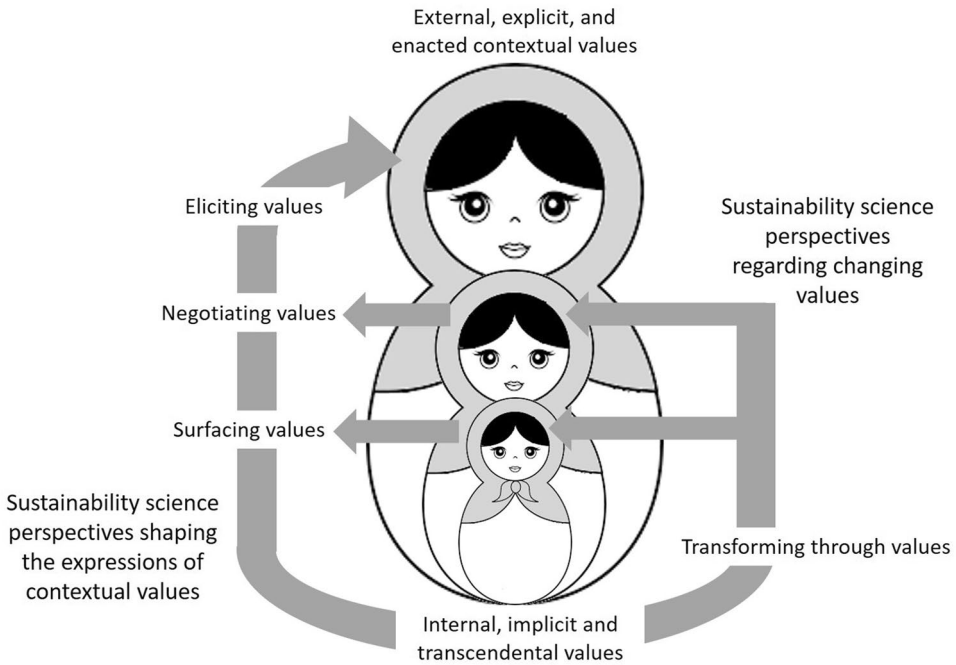

Fig. 1 Distilling the complexity of values concepts within transformational sustainability science in four perspectives. This visual analogy represents a heuristic that does not imply a linear progression or a hierarchy of elements of process. (Perspective 1) Surfacing implicit values: how values inform (scientific) understandings of how the world is. (Perspective 2) Negotiating values: whose values count in assessing states of the world. (Perspective 3) Eliciting values: how we elicit values ascribed to different states of the world. (Perspective 4) Transforming through values: using values as levers for changing states of the world. The four closely interrelated perspectives have different degrees of depth in undertaking value enquiries, or ultimately values related interventions, hence the rationale for using stacking elements for their visual representation

system as a whole. Two empirical examples are drawn from the iterative engagement and experiences of the approximately 25 interdisciplinary scientists working in the project (Tables 2, 3).

Perspective 1: Surfacing implicit values

The surfacing implicit values perspective is about the underpinning assumptions and norms shaping

Table 2 Example of engaging with Perspective 1 (Surfacing implicit values) within the Leverage Points project

The Leverage Points project has a formative accompanying research (FAR) work package, to study the experience of working together
The FAR work has sought to make implicit values visible to the team so that these are available for discussion. In sustainability, researchers may assume that their colleagues share the same underlying assumptions and norms. This can cause confusion when colleagues' research priorities or practices diverge from their own, or from stated project objectives.
To surface implicit values early on in the project, the FAR researcher did two things. First, she interviewed team members about the value of sustainability to them personally. She presented the team with headline results of these interviews so that all members were more aware of the range of implicit values, instead of blindly assuming homogeneity.
The interviews indicated:
(a) A range of personal priorities
E.g. *Sustainability is annoyingly central in my life; I can tie myself in knots worrying about it*
E.g. *Certain physical comforts are important to me and I won't give them up, even for reasons of sustainability*
(b) A range of assumptions about what it means to lead a sustainable life
E.g. *I no longer have a car, just a bicycle*
E.g. *For me, sustainability is less about riding a bicycle instead of a car. It's about being kind, having empathy, or taking responsibility for someone in trouble*
Second, the FAR researcher facilitated an exercise to make team members' epistemological assumptions and research practices more apparent to each other. During this exercise, the team explored assumptions about what would constitute success in the project. This generated 14 success criteria. Members of the team mapped the degree of convergence or divergence in their responses to these criteria, which included realising individual achievements and pursuing collective achievements. While unstated individual and collective ambitions could appear to be in conflict, surfacing their implicit underlying values makes it more possible to discuss different priorities and find overlapping values.

sustainability research. Sustainability is a normative concept with a vast array of overlapping and diverging understandings, theories, and narratives regarding its meaning (Schmieg et al. 2017). For example, the concept of sustainability appears to be more strongly derived from the Western culture rather than indigenous cultures (Van Kerkhoff and Lebel 2015; Sacks 2018). In turn, sustainability science is an unavoidably value-laden endeavour not only because of the mere notion it addresses, but also due to the values underpinning scientific understandings of the world and scientific institutions.

In addition to the way in which ontological assumptions about the nature of reality shape scientific enquiry (e.g., Blaikie 2008), scientists hold pre-analytic visions (Schumpeter 1954) that underpin and shape scientific models and research practices. Such pre-analytic visions are largely formed based on transcendental values, and relate to themes such as how we judge different states of the world, notions of progress and what we conceptualise as 'good'. For example, the notion of efficiency (defined as non-wastefulness) is a primary, normative measure by which resource allocation is judged. However, this value judgement underpinning economic thought potentially conflicts with the normative notion of ecological resilience premised on ideas of redundancy. The underlying transcendental values (for efficiency or resilience) fundamentally shape judgements about the sustainability of a particular system or even how such systems are defined and studied. Moreover, the inherently interdisciplinary sustainability science is embedded in an organisation of science shaped by ontological, epistemic and normative assumptions, as well as institutional and power structures (e.g., Fazey et al. 2018). Assumptions of scientific models are also institutionalised and reinforced via scientific traditions and disciplines (e.g., Raymond et al. 2010); thus, transcendental values create powerful, constraining, and rarely questioned narratives in the sciences.

Being aware of, and making transparent, the assumptions of the current epistemological and ontological models of the world may seem an ambitious task (Miller et al. 2014). However, ignoring them limits the opportunity space of sustainability science by reducing epistemological agility, or perpetuating false confounding or fragmented ontological meanings. Being more critical and reflective upon the process of theorising and conducting research requires that the transcendental values shaping the research processes and scientific institutions (such as the demand for 'global relevance' in research findings) are justified and made explicit (Jerneck et al. 2011; Spangenberg 2011). Studies that observe, or critically reflect on research practices are increasing (Wuelser and Pohl 2016). For example, making explicit the normative assumptions and goals associated with ecosystem services research has been suggested as a means of harnessing its transformational potential (Abson et al. 2014).

Ultimately, the challenge of sustainability science is to co-produce actionable knowledge for intervening on sustainability problems in a way that permits a plurality of values and perspectives to co-exist (Miller 2013). Therefore, especially within scientific research practices, surfacing and acknowledging the underpinning assumptions (or pre-analytic visions) of scientists are a vital first step. Transdisciplinary research practice characterised by actively involving actors outside academia provides a useful avenue for more explicit reflection on the constraining and enabling roles of underpinning transcendental values in sustainability science and transformational change (Popa et al. 2014). Starting with

problem framing, and going through all the main phases of the conceptual model of a transdisciplinary process (Lang et al. 2012), sustainability scientists make choices. Compared to research traditions where the values and norms shaping research are not explicitly discussed, in the case of transdisciplinarity, an essential role is played by a continuous dialogue and exchange between people from both scientific and societal bodies of knowledge. Sustainability problems are identified and bounded in value-explicit ways, as is the co-production and application of co-created knowledge (Ruppert-Winkel et al. 2015). Transdisciplinary research, and to a lesser extent interdisciplinary research, uses methodologies for eliciting and integrating the knowledge, goals, values, and norms of research participants, and translating them in the research design (e.g., Lang et al. 2012). Hence, by surfacing the tacit knowledge and the assumptions of diverse scientific backgrounds, transdisciplinary approaches allow generated knowledge to reflect multiple value systems in an integrated manner (Tschakert et al. 2016).

Value-laden assumptions within sustainability science often become less transparent when moving from abstract discussions (e.g., "What are the underpinning normative assumptions in ecosystem service research?") to concrete sustainability research projects (e.g., "How do we assess ecosystem services in this context?") (Fig. 1). Here, we argue that exploring the values underpinning and shaping individual research questions or projects is potentially fruitful for ensuring pluralistic problem framing and solution spaces. Particularly, in the case of science dealing with managing change, it is essential that researchers are aware of their own set of values, and their intended and possible role(s) as researchers (Wittmayer and Schäpke 2014), while explicitly providing time and space for self-reflection (Raymond et al. 2010). Such reflection gives researchers an inner-oriented understanding of reality. This under-considered aspect of sustainability science chimes with recent developments pointing to the importance of subjectivity and personal dimensions—the deep inner side—of sustainability transformation (Page et al. 2016; Fazey et al. 2018; Parodi and Tamm 2018) and goes back to the personal and tacit dimensions of knowledge of Michael Polanyi (1958) (see also Perspective 4).

Questions such as: "What are the normative assumptions that I bring to the research that I am carrying out?" and "How does this influence my choices about methodological and conceptual approaches?" are often overlooked, but especially important in the case of inter- and transdisciplinary sustainability research, where the lack of transparency can hinder or even undermine its results. As a practical starting point for Perspective 1, researchers may refer to the different continua of ontological, epistemological, and philosophical perspectives provided by the literature, for example, from an objectivist to a subjectivist approach (e.g., Moon and Blackman 2014; Raymond et al. 2014). Rawluk et al. (2019) also present a framework for mapping value concepts across ontology and epistemology, as well as different levels of abstractness and context dependency. These proxies for normative and value positions matter because they influence how sustainability science is conducted (choice of method, analysis, interpretation, and application) and the legitimacy of its outcomes. Tackling the above under-represented aspects and mapping how scientists through their positionalities build meaning and understand the world adds the needed nuance and transparency to the field of sustainability science (Jerneck et al. 2011, see also Table 2 for how we applied Perspective 1 to an ongoing research project). Finally, giving explicit consideration to value judgements that underpin scientific endeavours supports moving away from decision-making based solely on supposedly objective scientific information.

Perspective 2: Negotiating values

While Perspective 1 is concerned with the implicit values that scientists bring to transformational research, Perspective 2 focuses on the plurality of values that actors bring to participatory and group decision-making processes. This perspective asks questions around whose values count, how they are included, and how they shape participatory processes in sustainability science. Participatory approaches that seek to include values held by different actors generally enhance a solution orientation and the feasibility of sustainability interventions (Wiek et al. 2014). Solution strategies for sustainability problems require values to be expressed and understood during decision-making. Accounting for values, managing conflicts, and reconciling plural values builds civic participation and social legitimacy for the proposed transformational processes. This must be done at various scales of participation and by trading-off participants' views in the light of power relations (Bennett et al. 2015; Van Kerkhoff and Lebel 2015). Much of the focus in sustainability science has been on ensuring that all relevant stakeholders are included in participatory processes, where they are able to express their values (e.g., Leventon et al. 2016; Newig and Fritsch 2009). However, there is less focus in Perspective 2 on how the values of multiple stakeholders are negotiated in created shared positions or policies regarding specific sustainability challenges or contexts. We illustrate this under-represented element of the negotiating values perspective via the conceptual framework of Institutional Analysis and Development, IAD (Ostrom 2011).

The IAD framework (Ostrom 2011) provides a useful heuristic for understanding how social values are negotiated in group decision-making processes. It mentions different structural variables of existing institutional arrangements

that constrain and influence the outcomes of such decisions. This framework does not directly articulate the value systems of actors, but rather focuses on actors' influence on policy outcomes and how well these outcomes fit their interests. After defining a policy problem, the focus of the IAD analysis moves to behavioural aspects in the action arena, as influenced by the context (biophysical conditions, attributes of the community, and rules in use). The 'action' refers to those behaviours to which the acting individual or group attaches a subjective and instrumental meaning (Kiser and Ostrom 1982). As such, some of the operational concerns in this framework include the ways in which actors assign value to their resources, how their information, beliefs, and institutional constraints shape these valuations (see also Perspective 3), and which internal mechanisms they use to ultimately decide upon strategies (Ostrom and Cox 2010). The influence of contextual factors on the action situation could bring forward the idea of changing values deeply embedded in the socio-cultural context (Perspective 4).

Scholars use approaches such as the IAD to focus on negotiating values. This helps to identify the different normative rules and social values that determine change in decision-making strategies. However, the origin of the actors' individual values, which shape their original positions, is often ignored or under-considered. This is also evident in the fact that the discussion about conflicts across transcendental values is relatively neglected. More work is dedicated to reconciling contextual values tied to a specific sustainability challenge, action, or intervention (Kenter et al. 2016). With this caveat in mind, insights from social psychology theories of behaviour, e.g., Stern's (2000) value–belief–norm model, might be beneficial in developing tools for surfacing transcendental values in the incipient phases of participatory processes. This in turn might allow for a more open and transparent negotiation of the values and beliefs that shape collaboration, as well as for the development of shared goals in relation with transformational change.

Perspective 3: Eliciting values

Perspective 2 focuses on how transcendental values shape the outcomes of decision processes within opportunity spaces bounded by sustainability science and its underpinning assumptions (Perspective 1). In contrast, the eliciting values perspective engages with how contextual values can be elicited and aggregated to judge particular choices, objects, or actions related to specific sustainability challenges. This perspective asks questions about which ascribed values and associated valuation processes are used to inform decision-making and management processes: how we elicit social values related to potential changes in the state of the world, and how the types of elicited values and the methods for their assessment influence research outcomes and consequently decision-making processes. This perspective includes ethical discussions regarding the appropriateness of monetary and non-monetary valuations of changing states of the world (e.g., Gowdy 1997), along with more technical discussion regarding explicit valuation frameworks such as cost–benefit analysis (e.g., Wegner and Pascual 2011). While we use the example of value elicitation in relation with nature and biodiversity to illustrate this perspective, we argue that contextual values elicited in other fields, such as Likert scale style elicitations in environmental psychology and other social science disciplines, are similarly constraining.

Many disciplines devote immense effort to trying to categorise and assess the various values assigned to nature (Turner et al. 2003). However, most valuations of nature or landscapes fall into the realm of quantitative assessments, often with monetary assessments focusing on a subset of ascribed values that can easily be measured. Led in part by The Economics of Ecosystems and Biodiversity (TEEB 2010), quantification of environmental values or of benefits people derive from nature were encouraged to be compatible with other quantitative metrics used for decision-making, particularly economic ones (Gómez-Baggethun et al. 2010; Norgaard 2010). The basis for economic valuations is postulations within welfare economic theory, where it is believed that changes in human well-being can be measured in terms of utility expressed in exchange value. Consequently, whole socio-cultural contexts are reduced through quantitative assessments to monetary values, reinforcing the mainstreaming of economic rationales for valuation. For example, emotional attachment to nature or the whole spectrum of values assigned to (cultural) ecosystem services are not captured by many mainstream valuation processes, and are not translated in the values associated to potential changes in the state of the world (Milcu et al. 2013).

Using the restrictive language of economics to elicit contextual values related to changing states of the world can silence the voices of those expressing less anthropocentric values and preferences, such as ecosystem dependent communities, indigenous peoples or nature itself. Consequently, authors working in the field of ecosystem services have long argued that acknowledging and identifying the plurality of values that lie beyond monetary or even instrumental ones (e.g., Kumar and Kumar 2008; Pascual et al. 2017; Arias-Arévalo et al. 2018) is key to advancing towards sustainability transformation. While the hegemony of economics logic and its consequences in terms of contextual values and valuation methods of choice is recognised and criticised (e.g., Gómez-Baggethun et al. 2010; Abson and Termansen 2011), the deeply ingrained paradigm underpinning such valuation methods, that of control and subordination of nature is less talked about. Consequently, the majority of the available

valuation methods elicit values from the perspective of the current, arguably unsustainable economic system, not from the perspective of a desired state of the economic system (Norgaard 2010). Hence, similar to Perspective 1, one under-represented, yet relevant, aspect of this perspective consists of the inherent political and normative assumptions of methods and methodologies used to investigate values, and the relationship between the evaluating agent, the evaluated object or state, and the method used for valuation. As a response, scholars who argue for their transparency also call for valuation methods that are co-created. These are expected to help surface pluralistic, enacted contextual social values tightly linked with historic developments, local landscapes and cultural environments through which such values arise (Gunton et al. 2017). Moreover, such integrative valuation approaches allowing the expression of value plurality are more congruent with the multiple meanings of human well-being, of a good quality of life, and with concerns for the well-being of other beings. The movement that is rising in response to this under-recognised aspect and that is demanding the acceptance of multiple worldviews and associated values of nature has consolidated around, for example, a number of international science–policy platforms such as IPBES (2015) in its notion of nature's benefits to people and related approaches (Christie et al. 2019b). Another recent milestone in the extension of rationales for attributing value to nature beyond intrinsic and instrumental values is the introduction of relational values derived from all-encompassing human–nature relationships (Pascual et al. 2017). However, these movements also encounter challenging value conflicts associated with the different ways of eliciting values. Hence, we recognise that no form of value elicitation (or integration) can be presented as a panacea; rather, we need complementary approaches. Synergistic benefits should emerge from their co-existence and plurality (see also Perspective 2).

Another under-considered aspect of Perspective 3 stems from making explicit the dichotomy between transcendental and contextual values (Kenter et al. 2015). There is less research on the elicitation of transcendental (or first-order/held) values (Brown 1984), and on how such values influence second-order preferences/contextual values (Abson and Termansen 2011). Underlying transcendental values held by individuals are more difficult to aggregate to provide social values, than are second-order ascribed values that flow from them (Brown 1984). However, changes to transcendental values hold the greatest transformational potential as strong motivational driver that can explain human behaviour (Abson et al. 2017, Perspective 4). We suggest that deliberative valuation methods, co-produced through more transdisciplinary approaches, are potential ways to capture a broader range of values of nature (Raymond et al. 2014). Such methods also provide a means of eliciting explicit contextual social values related to specific states of the world that can also actively incorporate the exploration of transcendental social values (see also Perspective 4).

Perspective 4: Transforming through values

The first three values perspectives are based on surfacing, navigating, and eliciting existing social values related to sustainability transformations with the premise that better understanding such values can help foster desired societal change. In contrast, the transforming through values perspective engages with questions around interventions for activating (Raymond and Raymond 2019), nurturing, or shifting transcendental values as a means of facilitating transformational societal changes. The rationale is that transcendental values underpin individual behaviours and, at a collective level, the societal paradigms from which institutions, rules, and norms emerge. As such, this perspective adopts a complex system approach, with individuals at the same time being shaped by the system they are part of, and having the agency to shift (together with others) the goals of that system (Hausknost et al. 2016; Sacks 2018).

This perspective takes an interventionist stance: it assumes a certain degree of control of humans over their context, maintaining that people are able to reflect on and break through the structures that constrain them, as well as to take collective action for changing those structures. This perspective links values to notions such as triple-loop learning, which argues that outcomes of decision-making may not only improve practices (single-loop), but also lead to changes in the assumptions and values driving those practices (double-loop), and ultimately in the norms and broader context shaping the latter (triple-loop) (Armitage et al. 2008). Social learning is a closely related concept, as it emphasises, in certain conceptualizations, a change in understanding that is situated at wider social units than the individual and which takes place as a result of social interactions (Reed et al. 2010). The claim is that by creating shared spaces for joint deliberation and reflection, it is possible to influence a critical mass of people towards making decisions that benefit society. Participation processes, thus, become more than opportunities for negotiating values within a determinate action situation (Ostrom 2011), but are instances of broader and iterative societal engagement that can lead to changes in biophysical conditions, the attributes of the communities and the rules in use, i.e., can alter the context sensu IAD (see also Perspective 2). Horcea-Milcu et al. (2017), for instance, illustrate how shared transcendental values co-evolve in slow processes over time, and how central such processes are for ensuring the resilience of a cultural landscape.

Adherents to the transforming through values perspective also highlight the dynamic nature of values, with some explicitly linking societal learning processes to changes at the individual level. Van Riper et al. (2019) present a multi-level model of value shift through social learning and emphasise how individual and cultural values inform each other. Which conceptualization of values is employed matters a great deal in upholding such claims, with contextual values being seen as more malleable than transcendental ones (Kenter et al. 2015). Transcendental values appear to be both relatively slow to change and relatively stable (Ives and Kendal 2014; Fischer et al. 2012) compared to attitudes (i.e., an expression of contextual values), so processes of participatory group learning might be more likely to only trigger shifts in contextual values. Some authors also talk about such processes in terms of "value activation", suggesting that different contexts may awaken or bring forward different values, which consequently play a role in filtering information and setting goals (Verplanken et al. 2009). However, there is some recent empirical evidence that deliberative processes can also lead to more fundamental changes of values, i.e., target transcendental values (e.g., Raymond and Kenter 2016), although it is unclear whether such changes are lasting or not. To the extent to which transcendental values are regarded as the underlying canvas of behaviours—e.g., according to theories such as the value–belief–norm model by Stern (2000) or the behaviours–attitudes–values cognitive hierarchy model adapted from Fulton et al. (1996)—individual value change has potential to function as an intervention point for sustainability transformations. For example, Christie et al. (2019a) mention the notion of "ecological conversion", as a personal change of transcendental values towards sustainability. An open question remains, though, about which values support sustainable outcomes, how those values (and not others) can be activated, and by whom (Miller et al. 2014)? A potential answer comes from positive psychology which strives to activate pre-existent but hitherto not enacted desirable values (Raymond and Raymond 2019).

Following from this, one important partly under-considered aspect of Perspective 4 is that, at least in democratic societies, a critical mass of individual value change must be achieved to lead to visible changes in societal outcomes. As such, discussions often bleed into those of paradigms and dominant worldviews. For instance, some scholars adhering to the transforming through values perspective challenge the global paradigm of economic growth (D'Alisa et al. 2014), by calling for more reflexivity on the values underpinning it and for re-evaluating the goals that the economic system should serve (see also Perspective 3). While it may be possible to shift one's values (via e.g., deliberative processes) and trigger new individual behaviours, by which mechanisms would such shifts amount to widespread paradigm change at the level of an entire society?

One answer would point again to the link between individual and cultural values (van Riper et al. 2019). However, a second under-considered aspect of Perspective 4 is the claim of some scholars that it is not possible to influence the direction of a culture by changing individuals' values one at a time. Manfredo et al. (2017a, p. 775) maintain that values are "deeply entangled in a web of material culture, collective behaviours, traditions, and social institutions", and they are shaped by the context. As such, lasting value change is very slow and it is a consequence of other changes in the environment, as it follows from new behaviours, rather than precedes them (also see Manfredo et al. 2017b). In criticising the pretention of deliberate change that Perspective 4 inherently invokes, these authors plead instead for a focus on attitude, norm, and behaviour change in specific contexts (Manfredo et al. 2017a). Theorists of transition experiments (van den Bosch and Rotmans 2008) and transition initiatives (Gorissen et al. 2018) provide some insights into how phenomena that start out in niches might scale up to the level of an entire society by giving special attention to reflective learning, interaction, and experimentation at the level of society (see also McAlpine et al. 2015). As a result of such experiments, finding out whether values or behaviours should change first may amount to the chicken-and-the-egg question. The important effect is a shift in the dominant paradigm, i.e., a transformation. Within this context, individual agency and empowerment appear to play an important role, and the values underpinning personal action are part of the story (Westley et al. 2017). Along these lines, O'Brien (2018) considers the personal sphere of transformation, while Kendal and Raymond (2019) mention the influence of socio-psychological processes on the pathway of individual change for values shift.

This leads to a third under-considered aspect of Perspective 4, which pertains to the notion of personal sustainability (Parodi and Tamm 2018), and the relationship with oneself (Sacks 2018). Especially outside Western culture, inner dimensions of sustainability are considered as shaping the outside world. The processes taking place at individual level fundamentally affect the system level and are hence relevant for identifying the causes of the global sustainability deficit, as well as potential solutions (Villido 2018). As such, ignorance of the inner sphere and personal disconnections count among key causes for unsustainability (Villido 2018). In contrast, self-awareness of the values populating individual inner spaces, such as truth and love (Parodi 2018) paves the way to personal transformation that can foster our global transformation (O'Brien 2018). This under-considered notion of personal sustainability also echoes insights from psychology that concepts of "self" play a central role in

moderating the relationship between values and behaviours (Verplanken et al. 2009; Raymond and Raymond 2019).

Perspective 4 emphasises the role of individual value change in fostering societal transformations while also highlighting possible guiding mechanisms or approaches, such as empowerment and self-awareness for triggering it. Especially, in relation with Perspective 1, it opens sustainability science to enquiries into the role of scientists in fostering such changes, or in modelling specific values themselves. It also raises questions on whether shifting values requires our research to employ new methods of envisioning, of reflecting, and of engaging with others such as serious games. Table 3 exemplifies how we applied Perspective 4 within our ongoing 'Leverage Points' project.

Implications and future directions

Sustainability is a normative concept often suffering from the lack of agreement regarding what is worthwhile and meaningful. Values are generally narrowly considered inside each of the four perspectives, and even more rarely across them. Paradoxically, the ontological and epistemological richness surrounding values creates a complexity that is hard to navigate. Our four non-prescriptive perspectives help to distil and embrace this complexity. They offer guidance on where, and how to think about values when aiming for scientific activities contributing to transformational change. There are different situations in which one or more of the perspectives becomes helpful. Our paper sought to facilitate a sustainability research practice that changes between the different perspectives, depending on what is needed. The surfacing implicit values perspective draws attention to the normative choices hiding in scientific models, concepts and practices, and how they frame (in the broadest sense) the opportunity spaces for sustainability science. The negotiating values perspective focuses on unfolding the values of different actors involved in participatory settings, and how these shape the outcomes of decision processes within opportunity spaces delineated in Perspective 1. In contrast, the eliciting values perspective investigates attributing contextual and transcendental values in relation with specific changing states of the world, while the transforming through values perspective looks at the potential of individual value change or activation to function as intervention point for sustainability transformations. The four closely interrelated perspectives are not part of a linear progression, and do not imply a hierarchy of elements of process, yet have different degrees of depth in undertaking value enquiries or ultimately values related interventions (Fig. 1, Table 1). They range from internal reflection within science and society, and directions to reform sustainability science and practice (Perspective 1) to a more external (Perspective 3) and interventionist stance (Perspective 4). For example, social representation theory asserts that to foster a shared social ground and achieve further interactions, we need to understand the perspectives used by different individuals and communities (Perspective 2) prior to eliciting social values (Perspective 3). The perspectives also call for fundamental paradigm shifts either at the level of science (Perspective 1, 3) or at the level of society (Perspectives 2–4). Documenting how the perspectives shape, constrain and interact with each other, and proposing strategic ways to combine their different aspects according to the sustainability problem at hand, support mainstreaming value enquiries into transformational sustainability science.

We discuss key messages of the four perspectives in terms of their implications for (1) transformational scientific practice, (2) transformational research agendas, and (3) sustainability transformations in practice. Across the perspectives, transdisciplinarity, as one key sustainability research practice seems well suited to systematically incorporate

Table 3 Example of engaging with Perspective 4 (Transforming through values) within the Leverage Points project

Serious games are appealing in social processes for shaping decisions because they: (a) create immersive spaces to experiment with situations that are impossible in the real-world (e.g. switch of roles); (b) allow for testing novel solutions in a safe, risk-free space, where immediate feedback on consequences is provided; (c) dismantle real-life power relations and provide equal access to the game situation (Medema et al. 2016; Hummel et al. 2011; Katsaliaki and Mustafee 2012). As a consequence, they are thought of as tools for facilitating social learning, through processes of trust building, empathy exchange, and competence and skill development (Hummel et al. 2011).
In models of behaviour change used to understand the contribution of serious games to societal change, value change appears as one important mediating variable.
In our transdisciplinary work with farmers managing a pasture in a Saxon village in Transylvania, Romania, we used a serious game about contributing to a common good as a means to enhance collaboration. As reported in informal discussions with the participants, the process allowed for a levelling out of pre-existing roles and power dynamics, focusing the attention on the common interest in maintaining the resource. For the first time in several years, the neutral space provided by the game context enabled real-life "enemies" to meet and discuss joint strategies, changing their previously free-riding or conflictual behaviours, while at the same time building an understanding that they might actually share common interests.
As a one-time event, this may not equate with the deep transformational value change required for long-term collaboration, but game theoretic research on repetitive interactions (Axelrod and Hamilton 1981) opens a promising avenue for the hypothesis that serious games might have a role as transformational interventions in social–ecological systems.

transcendental values in transformation processes guided or informed by sustainability science. Transdisciplinarity is typically envisaged as a science–society collaboration that spans a broad range of disciplines and that involves the perspectives and interpretations of actors affected by the problem constellation under scrutiny (Lang et al. 2012; Popa et al. 2014). Nevertheless, consideration of values in transdisciplinary research theory and practice remains in its infancy. In addition, this research practice also faces other challenges, such as navigating the tension between allocating a lot of attention to the process at the expense of expediting outcomes, or balancing scientific rigor with societal relevance. However, it is precisely at these interfaces, where a space exists to bridge different actors' disparate, value-laden assumptions and transcendental values. In so doing, transdisciplinary approaches provide the possibility to make visible and ultimately co-generate more robust, legitimate, and transparent social values that act as a guide for sustainability transformations. Such approaches enable mutual learning between scientists rooted in different academic traditions and actors outside academia from different knowledge domains.

Similarly, when considering implications for transformational research agendas, the notion of holistic, integrative approaches for considering values in transformational change become key across all perspectives. Each perspective calls for holding space for more inclusive approaches for co-producing knowledge (Perspective 1), deliberative participatory practices (Perspective 2), value elicitation methods (Perspective 3), or a more holistic consideration of where to intervene in complex socio-ecological systems to effect transformational change (Perspective 4). This opening up of knowledge systems (Cornell et al. 2013) and widening of valuation methodologies (Arias-Arévalo et al. 2018) also aims to steer current transformational research beyond the dominant Western-style scientific-rational way of seeing the world to include currently under-considered aspects in the values perspectives, such as indigenous and local knowledge (Van Kerkhoff and Lebel 2015). More reflexive and co-created approaches of operationalizing values in relation with transformational change are better tailored for the heterogeneity and complexity of value understandings.

For future research agendas, value shifts are probably not the *holy grail* of transformational change, yet they have the potential to go beyond incremental change. Values are theoretically associated with deep leverage points (Abson et al. 2017; Fischer et al. 2012), where interventions can lead to fundamental system transformation, as opposed to interventions at shallow leverage points such as modifying parameters or altering feedback loops in resource use (Meadows 1999) (see also Fig. 1). Kendal and Raymond (2019) point towards ways in which this potential could be leveraged over time, such as shifts in transcendental values in response to societal development or economic circumstances. Moreover, social values emerging from sustainability science processes (Perspective 1), or actively changed via such processes (Perspective 4) may determine our ability to envision and design systems to fulfil our needs in a just and sustainable manner (Abson et al. 2017). Similarly, by explicitly considering how different transcendental and contextual values are navigated and expressed in social processes related to transformational change we open the prospect for transdisciplinary processes that better reflect what those societal needs are (rather than imposing understandings of those needs for specific traditions of science).

At the level of sustainability transformations in practice, the four perspectives invite reflexive introspection from sustainability scientists themselves (Perspective 1, Popa et al. 2014; Wittmayer and Schäpke 2014), and from actors in other societal domains (Perspective 4, Ives et al. 2018). Weaving self-reflection and self-awareness in everyday research practice might be a way forward for researchers' interactions among themselves, with young scholars or societal stakeholders (Lang et al. 2017). Our calls to enliven the inner dimensions of sustainability and transformation through reflexive practices and habits of mind set a clear agenda for scientists and policymakers to move beyond the discomfort created by such a deep and complex concept by embracing its complexity.

Praxis recommendations

To incorporate social values in transformational processes and critically deal with their plurality, we suggest that there is a need to actively reflect on one's own positionality in relation with the particular operationalization of values identified in the four values perspectives. This requires organising deliberative fora to surface how these different faces of social values shape sustainability science and transformational processes. When multiple actors are involved (in surfacing, negotiating or eliciting values), engaging a 'values broker' may help mediate between the expressed competing values to prevent conflict (see e.g., Ingold and Varone 2012) or shape consensus. Unpacking and negotiating conflicting values through deliberation are also likely to affect what transcendental values and preferences people express. This calls for a new negotiation and agreement on the terms of deliberation at the incipient phases of participatory and elicitation processes that facilitate and inform decision-making. Similarly, the impact of how values are ascribed and elicited for guiding policy formation and for being incorporated into policies needs to be assessed. It is increasingly apparent that the terms of deliberation or valuation do not necessarily need to lead to unanimous consensus, but rather plastic ways to deal with value conflicts while maintaining the naturally occurring plurality of expressed differences. Seeing that

sustainability is considered a collective balancing act involving a continuous process of negotiation of social values and interests (Loorbach et al. 2011), the four perspectives presented here help articulate a collaborative approach to policy and practice that promotes mutual learning between practice and science.

Conclusion

By examining different ways to operationalize values in transformational sustainability science, this paper provides a foundation for advancing a value-based perspective in transformational research, from which to further develop sustainability theory and transformational practice. Explicit recognition of the four interconnected perspectives can help sustainability scientists to: (1) move beyond general discussions implying that values matter while being vague about how and where, (2) gain an awareness of the positionality of one's own values perspective when undertaking values related sustainability research, and (3) reflect on the operationalizations of values in different contexts such as those shaped by local perspectives. While it is important to recognise that our categorization of four values perspectives in relation with sustainability science and transformational change does not encompass the diversity of narratives around values and change in the literature, we believe that it can enable boundary work at the science–policy–society interface for sustainability transformation. There would be numerous rewards from bringing such a hidden topic to light.

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References

Abson DJ, Termansen M (2011) Valuing ecosystem services in terms of ecological risks and returns. Conserv Biol 25:250–258

Abson DJ, von Wehrden H, Baumgärtner S, FischeraJ, Hanspach J, Härdtle W, Heinrichs H, Klein AM, Lang DJ, Martens P, Walmsley D (2014) Ecosystem services as a boundary object for sustainability. Ecol Econ 103:29–37

Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, von Wehrden H, Abernethy P, Ives CD, Jager NW, Lang DJ (2017) Leverage points for sustainability transformation. Ambio 46:30–39

Arias-Arévalo P, Gómez-Baggethun E, Martín-López B, Pérez-Rincón M (2018) Widening the evaluative space for ecosystem services: a taxonomy of plural values and valuation methods. Environ Values 27:29–53

Armitage D, Marschke M, Plummer R (2008) Adaptive co-management and the paradox of learning. Glob Environ Change 18:86–98

Axelrod R, Hamilton WD (1981) The evolution of cooperation. Science 211(4489):1390–1396

Bennett EM, Cramer W, Begossi A, Cundill G, Díaz D, Egoh NG, Geijzendorffer IR, Krug CB, Lavorel S, Lazos E, Louis L, Martín-López B, Meyfroidt P, Mooney HA, Nel LN, Pascual U, Payet K, Pérez Harguindeguy N, Peterson GD, Prieur-Richard A, Reyers B, Roebeling P, Seppelt R, Solan M, Tschakert P, Tscharntke T, TurnerII BL, Verburg PH, Viglizzo EV, White PCL, Woodward G (2015) Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr Opin Environ Sustain 14:76–85

Blaikie N (2008) Approaches to social enquiry. Polity Press, Cambridge

Brown TC (1984) The concept of value in resource allocation. Land Econ 60:231

Christie I, Richard G, Hejnowicz AP (2019a) Sustainability and the common good: catholic social teaching and "integral ecology" as contributions to a framework of social values for sustainability transitions. Sustain Sci **(in review)**

Christie M, Martin-Lopez B, Church A, Siwicka E, Szymonczyk P, Keune H, Sauterel JM, Kretsch C (2019b) Inclusive valuation of nature's contributions to people: the IPBES Europe and Central Asia assessment. Sustain Sci **(in review)**

Cornell S, Berkhout F, Tuinstra W, Tàbara JD, JägerJ, Chabay I, de Wit B, Langlais R, Mills D, Moll P, Otto IM, Petersen A, Pohl C, van Kerkhoff L (2013) Opening up knowledge systems for better responses to global environmental change. Environ Sci Policy 28:60–70

D'Alisa G, Demaria F, Kallis G (eds) (2014) Degrowth: a vocabulary for a new era. Routledge, New York

Dietz T, Fitzgerald A, Shwom R (2005) Environmental values. Annu Rev Environ Resour 30:335–372

Fazey I, Schäpke N, Caniglia G, Patterson J, Patterson J, Hultman J, van Mierlo B, Säwe F, Wiek A, Wittmayer JM, Aldunce P, Al Waer H, Battacharya N, Bradbury H, Carmen E, Colvin J, Cvitanovic C, D'Souza M, Gopel M, Goldstein B, Hämäläinen T, Harper G, Henfry T, Hodgson A, Howden MS, Kerr A, Klaes M, Lyon C, Midgley G, Moser S, Mukherjee N, Müller K, O'Brien K, O'Connell DA, Olsson P, Page G, Reed MS, Searle B, Silvestri G, Spaiser V, Strasser T, Tschakert P, Uribe-Calvo N, Waddell S, Rao-William J, Wise R, Wolstenholme R, Woods M, Wyborn C (2018) Ten essentials for action oriented and second order energy transitions, transformations and climate change research. Energy Res Soc Sci 40:54–70

Fischer J, Dyball R, Fazey I, Gross C, Dovers S, Ehrlich PR, Brulle RJ, Christensen C, Borden RJ (2012) Human behavior and sustainability. Front Ecol Environ 10:153–160

Fulton DC, Manfredo MJ, Lipscomb J (1996) Wildlife value orientations: a conceptual and measurement approach. Hum Dimens Wildl 1:24–47

Gómez-Baggethun E, de Groot R, Lomas PL, Montes C (2010) The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. Ecol Econ 69:1209–1218

Gorissen L, Spira F, Meynaerts E, Valkering P, Frantzeskaki N (2018) Moving towards systemic change? Investigating acceleration dynamics of urban sustainability transitions in the Belgian City of Genk. J Clean Prod 173:171–185

Gowdy JM (1997) The board of regents of the university of Wisconsin system the value of biodiversity: markets, society, and ecosystems. Land Econ 7340:25–41

Gunton RM, van Asperen EN, Basden A, Bookless D, Araya Y, Hanson DR, Goddard MA, Otieno G, Jones GO (2017) Beyond ecosystem services: valuing the invaluable. Trends Ecol Evol 32:249–257

Hausknost D, Gaube V, Haas W, Smetschka B, Lutz J, Singh JS, Schmid M (2016) Society can't move so much as a chair!—systems, structures and actors in social ecology. In: Haberl H, Fischer-Kowalski M, Krausmann F, Winiwarter V (eds) Social ecology: society-nature relations across time and space. Springer, New York, pp 125–147

Horcea-Milcu AI, Abson DJ, Dorresteijn I, Loos J, Hanspach J, Fischer J (2017) The role of coevolutionary development and value change debt in navigating transitioning cultural landscapes: the case of Southern Transylvania. J Environ Plan Manag 61:800–817

Hummel HGK, van Houcke J, Nadolski RJ, van der Hiele T, Kurvers H, Löhr A (2011) Scripted collaboration in serious gaming for complex learning: effects of multiple perspectives when acquiring water management skills. Br J Educ Technol 42:1029–1041

IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2015) Preliminary guide regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services

Ingold K, Varone F (2012) Treating policy brokers seriously: evidence from the climate policy. J Public Adm Res Theory 22(2):319–346

Ives CD, Kendal D (2014) The role of social values in the management of ecological systems. J Environ Manag 144:67–72

Ives CD, Abson DJ, von Wehrden H, Dorninger C, Klaniecki K, Fischer J (2018) Reconnecting with nature for sustainability. Sustain Sci 13:1389–1397

Jerneck A, Olsson L, Ness B, Anderberg S, Baier M, Clark E, Hickler T, Hornborg A, Kronsell A, Lövbrand E, Persson J (2011) Structuring sustainability science. Sustain Sci 6:69–82

Katsaliaki K, Mustafee N (2012) A survey of serious games on sustainable development. In: Proceedings of the winter simulation conference, WSC'12. pp 136:1–136:13

Kendal D, Raymond CM (2019) Understanding pathways to shifting people's values over time in the context of social–ecological systems. Sustain Sci **(this issue)**

Kenter JO, O'Brien L, Hockley N, Ravenscroft N, Fazey I, Irvine KN, Reed MS, Christie M, Brady E, Bryce R, Church A (2015) What are shared and social values of ecosystems? Ecol Econ 111:86–99

Kenter JO, Bryce R, Christie M, Cooper N, Hockley N, Irvine KN, Fazey I, O'Brien L, Orchard-Webb J, Ravenscroft N, Raymond CM, Reed MS, Tett P, Watson V (2016) Shared values and deliberative valuation: future directions. Ecosyst Serv 21:358–371

Kiser LL, Ostrom E (1982) The three worlds of action: a metatheoretical synthesis of institutional approaches. In: Ostrom E (ed) Strategies of political inquiry. Sage, Beverly Hills, pp 179–222

Kumar M, Kumar P (2008) Valuation of the ecosystem services: a psycho-cultural perspective. Ecol Econ 64(4):808–819

Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M, Thomas CJ (2012) Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain Sci 7:25–43

Lang DJ, Wiek A, von Wehrden H (2017) Bridging divides in sustainability science. Sustain Sci 12:1–5

Leventon J, Fleskens L, Claringbould H, Schwilch G, Hessel R (2016) An applied methodology for stakeholder identification in transdisciplinary research. Sustain Sci 11:763–775

Loorbach D, Frantzeskaki N, Thissen W (2011) A transition research perspective governance for sustainability. In: Jaeger C, Tàbara JD, Jaeger J (eds) European research on sustainable development. Springer, Berlin, pp 73–89

Manfredo MJ, Bruskotter JT, Teel TL, Fulton D, Schwartz SH, Arlinghaus R, Oishi S, Uskul AK, Redford K, Kitayama S, Sullivan L (2017a) Why social values cannot be changed for the sake of conservation. Conserv Biol 31:772–780

Manfredo MJ, Bruskotter JT, Teel TL, Fulton D, Oishi S, Uskul AK, Redford K, Schwartz SH, Arlinghaus R, Kitayama S, Sullivan L (2017b) Revisiting the challenge of intentional value shift: reply to Ives and Fischer. Conserv Biol 31:1486–1487

McAlpine C, Seabrook LM, Ryan JG, Feeney JF, Ripple WJ, Ehrlich AH, Ehrlich PR (2015) Transformational change: creating a safe operating space for humanity. Ecol Soc 20(1):56

Meadows D (1999) Leverage points: places to intervene in a system. The Sustainability Institute, Hartland

Medema W, Furber A, Adamowski J, Zhou Q, Mayer I (2016) Exploring the potential impact of serious games on social learning and stakeholder collaborations for transboundary watershed management of the St. Lawrence River Basin. Water 8:175

Milcu A, Hanspach J, Abson D, Fischer J (2013) Cultural ecosystem services: a literature review and prospects for future research. Ecol Soc 18:44

Miller TR (2013) Constructing sustainability science: emerging perspectives and research trajectories. Sustain Sci 8:279–293

Miller TR, Wiek A, Sarewitz D, Robinson J, Olsson L, Kriebel D, Loorbach D (2014) The future of sustainability science: a solutions-oriented research agenda. Sustain Sci 9:239–246

Moon K, Blackman D (2014) A guide to understanding social science research for natural scientists. Conserv Biol 28:1167–1177

Newig J, Fritsch O (2009) Environmental governance: participatory, multi-level - and effective? Environ Policy Gov 19:197–214

Norgaard RB (2010) Ecosystem services: from eye-opening metaphor to complexity blinder. Ecol Econ 69:1219–1227

O'Brien K (2018) Is the 1.5 °C target possible? exploring the three spheres of transformation. Curr Opin Environ Sustain 31:153–160

Ostrom E (2011) Background on the institutional analysis and development framework. Policy Stud J 39:7–27

Ostrom E, Cox M (2010) Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis. Environ Conserv 37:451–463

Page GG, Wise RM, Lindenfeld L, Moug P, Hodgson A, Wyborn C, Fazey I (2016) Co-designing transformation research: lessons learned from research on deliberate practices for transformation. Curr Opin Environ Sustain 20:86–92

Parodi O (2018) Sustainable development: a matter of truth and love. In: Parodi O, Tamm K (eds) Personal sustainability: exploring the far side of sustainable development. Routledge, New York, pp 65–82

Parodi O, Tamm K (2018) Personal sustainability: exploring the far side of sustainable development. Routledge, New York

Pascual U, Balvanera P, Díaz S, Pataki G, Roth E, Stenseke M, Watson RT, Başak Dessane E, Islar M, Kelemen E, Maris V, Quaas M, Subramanian SM, Wittmer H, Adlan A, Ahn S, Al-Hafedh YS, Amankwah E, Asah ST, Berry P, Bilgin A, Breslow SJ, Bullock C, Cáceres D, Daly-Hassen H, Figueroa E, Golden CD, Gómez-Baggethun E, González-Jiménez D, Houdet J, Keune H, Kumar R, Ma K, May PH, Mead A, O'Farrell P, Pandit R, Pengue W, Pichis-Madruga R, Popa F, Preston S, Pacheco-Balanza D, Saarikoski H, Strassburg BB, van den Belt M, Verma M, Wickson F, Yagi N (2017) Valuing nature's contributions to people: the IPBES approach. Curr Opin Environ Sustain 26–27:7–16

Polanyi M (1958) Personal knowledge. Towards a post-critical philosophy. Routledge, London

Popa F, Guillermin M, Dedeurwaerdere T (2014) A pragmatist approach to transdisciplinarity in sustainability research: from complex systems theory to reflexive science. Futures 65:45–56

Rawluk A, Ford R, Anderson N, Williams K (2019) Exploring multiple dimensions of values and valuing: a conceptual framework for mapping and translating values for research and practice. Sustain Sci **(this issue)**

Raymond CM, Kenter J (2016) Transcendental values and the valuation and management of ecosystem services. Ecosyst Serv 21:241–257

Raymond IJ, Raymond CM (2019) Positive psychology perspectives on social values and their application to intentionally delivered sustainability interventions. Sustain Sci **(in review)**

Raymond CM, Fazey I, Reed MS, Stringer LC, Robinson GM, Evely AC (2010) Integrating local and scientific knowledge for environmental management. J Environ Manag 91:1766–1777

Raymond CM, Kenter J, Turner N, Alexander K (2014) Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services. Ecol Econ 107:145–156

Reed M, Evely A, Cundill G, Fazey I, Glass J, Laing A, Newig J, Parrish B, Prell C, Raymond CM, Stringer LC (2010) What is social learning? Ecol Soc 15:4

Ruppert-Winkel C, Arlinghaus R, Deppisch S, Eisenack K, Gottschlich D, Hirschl B, Matzdorf B, Mölders T, Padmanabhan M, Selbmann K, Ziegler R, Plieninger T (2015) Characteristics, emerging needs, and challenges of transdisciplinary sustainability science: experiences from the German Social-Ecological Research Program. Ecol Soc 20(3):13

Sacks S (2018) Sustainability without the I-sense is nonsense Inner 'technologies' for a viable future and the inner dimension of sustainability. In: Parodi O, Tamm K (eds) Personal sustainability: exploring the far side of sustainable development. Routledge, New York, pp 171–188

Schmieg G, Meyer E, Schrickel I, Herberg J, Caniglia G, Vilsmaier Ulli, Laubichler M, Hörl E, Lang D (2017) Modeling normativity in sustainability: a comparison of the sustainable development goals, the Paris agreement, and the papal encyclical. Sustain Sci 13(3):785–796

Schumpeter JA (1954) History of economic analysis. Routledge, London

Schwartz SH (1992) Universals in the content and structure of values: theoretical advances and empirical tests in 20 countries. Adv Exp Soc Psychol 25:1–65

Schwartz SH (2012) An overview of the Schwartz theory of basic values. Online Read Psychol Cult 2:1–18

Seidl R, Brand FS, Stauffacher M, Krütli P, Le QB, Spörri A, Meylan G, Moser C, González MB, Scholz RW (2013) Science with society in the anthropocene. Ambio 42:5–12

Spangenberg JH (2011) Sustainability science: a review, an analysis and some empirical lessons. Environ Conserv 38:275–287

Stern PC (2000) Toward a coherent theory of environmentally significant behavior. J Soc Issues 56:407–424

Tadaki M, Sinner J, Chan KMA (2017) Making sense of environmental values: a typology of concepts. Ecol Soc 22(1):7

TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB

Tschakert P, Tuana N, Westskog H, Koelle B, Afrika A (2016) TCHANGE: the role of values and visioning in transformation science. Curr Opin Environ Sustain 20:21–25

Turner RK, Paavola J, Cooper P, Farber S, Jessamy V, Georgiou S (2003) Valuing nature: lessons learned and future research directions. Ecol Econ 46:493–510

Van den Bosch S, Rotmans J (2008) Deepening, broadening and scaling up: a framework for steering transition experiments. Knowl Cent Sustain Syst Innov Transit 3–64

Van Riper C, Winkler-Schor S, Stamberger L, Keller R, Braito M, Raymond C, Eriksson M, Golebie E, Johnson D (2019) Integrating multi-scale values and pro-environmental behavior in a protected area. Sustain Sci **(in review)**

Van Kerkhoff LE, Lebel L (2015) Coproductive capacities: rethinking science-governance relations in a diverse world. Ecol Soc 20:14

Verplanken B, Trafimow D, Khusid IK, Holland RW, Steentjes GM (2009) Different selves, different values: effects of self-construals on value activation and use. Eur J Soc Psychol 39:909–919

Villido I (2018) Awareness as the new paradigm for personal sustainability. A practitioner' s perspective on the sustainability transition. In: Parodi O, Tamm K (eds) Personal sustainability: exploring the far side of sustainable development. Routledge, New York, pp 136–150

Wegner G, Pascual U (2011) Cost-benefit analysis in the context of ecosystem services for human well-being: a multidisciplinary critique. Glob Environ Change 21:492–504

Westley F, McGowan K, Tjörnbo O (2017) The evolution of social innovation. Edward Elgar Publishing, Cheltenham

Wiek A, Talwar S, O'Shea M, Robinson J (2014) Toward a methodological scheme for capturing societal effects of participatory sustainability research. Res Eval 23:117–132

Wittmayer JM, Schäpke N (2014) Action, research and participation: roles of researchers in sustainability transitions. Sustain Sci 9:483–496

Wuelser G, Pohl C (2016) How researchers frame scientific contributions to sustainable development: a typology based on grounded theory. Sustain Sci 11:789–800