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Winkler-Portmann, Simon J.

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Knowledge transfer supporting sustainable development: implications for regional intermediaries

Simon J. Winkler-Portmann*

*Society for Institutional Analysis – sofia, University of Applied Sciences, Darmstadt, Germany

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Abstract

The wicked sustainability challenges of current socio-technical systems, crossing the planetary boundaries vital for human life, call for fundamental and radical change in the form of transitions. These sustainability transitions require a knowledge basis of relevant actors in the system, which intermediary structures organizing knowledge transfer can support. Over the last decades, sustainability researchers have not only increasingly studied the dynamics of transitions (Rip and Kemp 1998; Geels 2002; Papachristos et al. 2013), but have also gained insights on activities contributing to the acceleration of transitions and the supportive role of intermediaries in that regard (Wieczorek and Hekkert 2012; Kanda et al. 2018; Kivimaa et al. 2019). This paper revisits the literature on the dynamics of transitions, the activities of intermediaries in contributing in order to formulate implications of the characteristics of sustainable development and sustainability transitions and the related knowledge types for the organization of knowledge transfer by regional intermediaries.

Content

1
Introduction

Socio-technical systems, i.e. the configurations of actors, technologies and institutions[1] (Schot and Kanger 2018; Geels et al. 2004), which fulfil specific societal functions such as personal mobility or energy (Geels et al. 2017), currently develop on an unsustainable pathway. Thus, several of the planetary boundaries that are vital for the continuation of human life on earth, have been crossed, and even more are at a critical level (Rockström et al. 2009). Moreover, the frequency, scale and severity of these sustainability challenges appear to be increasing, as shown, inter alia, by recent reports from the Intergovernmental Panel on Climate Change (IPCC 2018). The Sustainable Development Goals (SDGs) declared by the United Nations in its 2030 Agenda show the broad range of unsustainability aspects which humanity needs to address, from poverty to gender equality to ocean conservation (United Nations 2015). Due to their complexity, sustainability challenges have been characterized as 'wicked problems', because they are highly complex and difficult to specify as cause and effect relations are unknown (Blok et al. 2016; Wehrden et al. 2017; Urmetzer et al. 2018).

Innovation plays an important role in addressing these unsustainable development patterns (Clune and Zehnder 2020), as it extends the range of action (Schneidewind 2018). However, as the unsustainable practices of current socio-technical systems and the respective innovations have led to the wicked sustainability challenges, expectations regarding innovatory developments must not be limited to incremental technological innovations, but rather directed towards transitions that shift the development to a different pathway (Hoogma 2002; Geels and Kemp 2007; Beers and van Mierlo 2017).

Such transitions describe the radical and fundamental change from one socio-technical system to another, as an adjustment to changed internal and external circumstances (van Lente et al. 2003; Geels and Schot 2010; Rotmans and Loorbach 2010). This change not only affects elements of the system, but its entire structure or functioning (Geels et al. 2004; Rotmans and Loorbach 2010). They are thus not to be confused with 'technological revolutions', which do not change functionalities of systems (Geels et al. 2004). Sustainability transitions are a specific form of such socio-technical transitions which are directed towards a more sustainable state (Loorbach and Rotmans 2006; Gaziulusoy et al. 2013). In that, they constitute a response to the wicked sustainability problems such as climate change (Grin et al. 2010).

These sustainability transitions require a knowledge basis. (Schneidewind 2018). In reference to the fundamental understanding of knowledge as the

[1] Socio-technical systems include aspects such as infrastructure, supply networks, regulations, cultural meanings and user practices, but do not refer to sectors (Schot and Kanger 2018; Geels et al. 2004).

"solution to problems" (Potts 2001, p. 418), knowledge transfer supports the acceleration of sustainability transitions. At the same time, institutionalized knowledge often determines the direction of progress, supporting the path dependency of innovation in socio-technical systems and impeding change processes (Urmetzer et al. 2020). Regional intermediaries organizing knowledge transfer for sustainable development therefore have to provide a structure that supports the important knowledge basis for sustainability transitions while not creating additional impediments.

Over the last decades, sustainability researcher have not only increasingly studied the dynamics of transitions (Rip and Kemp 1998; Geels 2002; Papachristos et al. 2013), but have also gained insights on activities contributing to the acceleration of transitions and the supportive role of intermediaries in that regard (Wieczorek and Hekkert 2012; Kanda et al. 2018; Kivimaa et al. 2019). This paper revisits the basics in order to formulate implications of the characteristics of sustainable development and sustainability transitions and the related knowledge types for the organization of knowledge transfer by regional intermediaries.

With the methodological approach described in the next section, the third section reflects on the research discussion in literature on innovation in the context of sustainable development. The fourth section describes the role of knowledge in this context. Section five then presents hypotheses concerning prerequisites for regional intermediaries, which expected to contribute to foster sustainable development.

2
Methodology

As a basis for the formulation of implications of sustainable development and sustainability transitions for the knowledge transfer by regional intermediaries, the author conducted a semi-systematic literature review. For that, he first searched common literature databases for the keywords "sustainability" and "sustainable development" as well as a combination of those words with "innovation" and "knowledge". The search included a search for the keywords "transition" and "system innovation" with and without a further combination with "sustainability" and "sustainable development". The author then identified relevant literature from the results. Based on the references in this first-degree literature, additional relevant literature was identified.

In a first analysis of the identified literature, the author tried to gain insights regarding the characteristics of sustainable development concerning innovation and the particularities of (sustainability) transitions (chapter 3). A second string of analysis concerned the research on knowledge in the context of sustainable development (chapter 4). Both aspects were then analysed regarding implications for the knowledge transfer organized by regional intermediaries.

3
Innovation in the context of sustainable development

Sustainable development as a concept has been subject to a broad academic discussion around its interpretation. This already starts with the terminology, as some researchers refer to "sustainable development", while others use the term "sustainability". Some scholars prefer "sustainability," insisting that "sustainable development" focuses more on economic aspects and can be misinterpreted as sustained economic growth (Waas et al. 2011). Others prefer "sustainable development" to emphasize the dynamic aspect, depicting sustainability as a normative goal that sustainable development as a process aims to achieve (Michelsen et al. 2016). This section presents the academic discussion first, then analysing the specifics of sustainable development and sustainability transitions discusses implications for sustainability innovation.

3.1
Characteristics of sustainable development

Scholars have emphasized different aspect of sustainable development. Some consider it as an anthropocentric concept (Smith 2019), focused on how people can live in harmony with each other and with nature (Waas et al. 2011). Others instead focus on resilience, i.e. the ability of human, natural or mixed systems to manage change (Dovers and Handmer 1992). Despite the vital discussion, sustainable development can be understood through several principles, which have been elaborated and refined over the years.

The report of the UN World Commission on Environment and Development, also called Brundtland Commission,[2] laid ground for the modern understanding of sustainability by stating: "Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future" (World Commission on Environment and Development 1987, no. 4949). It thereby established the principle of inter- and intragenerational equity (Dovers and Handmer 1992; Waas et al. 2011; Michelsen et al. 2016) and acknowledged the preservation of natural resources as a central condition for prosperity (Schneidewind 2018). This refers to the insight that economy, society and ecology are interrelated and interdependent (Michelsen et al. 2016; Padilla 2019). Some scholars define the ecological aspect as "interspecies" equity, dropping the anthropocentric interpretation of the Brundtland report by attributing an intrinsic / inherent right to life to plants and animals (Waas et al. 2011; Dovers and Handmer 1992). Others emphasize the Brundtland reports global perspective by adding "geographical equity", referring to cooperation from the local to the global level and accounting for different circumstances (Waas et al. 2011; Michelsen et al. 2016).

[2] Named after the former Norwegian Prime minister Gro Harlem Brundtland which lead the commission (Michelsen et al. 2016, pp. 11–12).

Based on the definition of the Brundtland Commission, scholars have developed various models with a multitude of dimensions to illustrate sustainability and its principles. For a long time, the three pillar model, also called "triple bottom line", has been the most common model (Waas et al. 2011). The three dimensions for economic, environmental and social aspects are often depicted as three intersecting circles or an equilateral triangle (Waas et al. 2011; Smith 2019). However, the three pillars model has been criticized for promoting a siloed conception of the dimensions (Elder and Olsen 2019) which are often interpreted as independent kinds of capital that can be substituted by other types (Michelsen et al. 2016; Gaziulusoy 2015).

This concept has been called "weak sustainability" in opposition to "strong sustainability" which sees environmental, economic and social aspects as interrelated and complementary dimensions that can only be substituted to a limited extent (Michelsen et al. 2016; Gaziulusoy 2015). As a result, the three-pillar model is no longer widely accepted in the research community for sustainable development (Elder and Olsen 2019). Alternative models underline the natural environment as a basis for social welfare and economic development in a nested depiction, with the ecologic dimension surrounding societal dimension which itself surrounds economic dimension (e.g. Giddings et al. 2002). This model can also be applied to the Sustainable Development Goals, such as the 'wedding cake model' which organizes the goals 1 to 16 in three layers biosphere, society and economy (Stockholm Resilience Centre 2016), although the SDGs are often difficult to assign to a single dimension (Elder and Olsen 2019). Such a hierarchical conceptualization shows that there absolute limits to trade-offs between dimensions if a functioning life-support system is to be maintained (Fischer et al. 2007). To illustrate the physical limits of the ecological environment, some sustainable development scholars such as Schneidewind 2018 reference the 'planetary boundaries' concept established by Rockström et al. 2009. Scholars of the 'doughnut economics' depict the planetary boundaries as an 'environmental ceiling', which together with a 'social foundation' provide boundaries for a sustainable economic development (Raworth 2012, 2017).

Considering the conflicts between the three dimensions, scholars have increasingly emphasized governance as an institutional fourth dimension of sustainability, which organizes the change processes towards sustainable development (Waas et al. 2011; Schneidewind 2018). Governance in that understanding refers to all "structures, processes, rules and traditions that determine how people in societies make decisions and share power, exercise responsibility and ensure accountability" (Patterson et al. 2017, p. 3), which are not solely created by governments, but also through multi-stakeholder collaboration (Florini and Pauli 2018). The four-dimensional approach is also indicated in the wedding cake model, which sees goal 17, "partnership for the goals", as the vertical axis, keeping the other three dimensions in order (Stockholm Resilience Centre 2016).

The principle of equity as well as the discussion around models show the normative character of sustainable development. Rather than being an scientifically observed fact, sustainability constitutes a socially constructed ethical concept (Michelsen et al. 2016). More specifically, sustainability "provides a vision of a desirable state of what the future should look like, alongside a set of rules that indicate what ought to happen for this state to be reached" (Schlaile et al. 2017, p. 3), thereby describing a desirable direction of change (Urmetzer et al. 2018). How societal actors envision the desired state as well as the pathway leading there, is largely influenced by their particular worldviews and values (Waas et al. 2011; Schlaile et al. 2017), making sustainable development a subjective concept (Waas et al. 2011). As a result, when planning sustainability contributions, social decision-making processes with broad stakeholder participation are required to account for different perspectives (Meppem and Gill 1998; Michelsen et al. 2016).

Sustainable development is a continuous evolutionary process with a specific orientation, towards sustainability, but without an end point (Meppem and Gill 1998; Waas et al. 2011). The target is "updated on a continuous basis as a result of continuously improving understanding of dynamic conditions of sustainability" (Gaziulusoy et al. 2013, p. 105). Political goals, too, are always only interim goals and must constantly be adapted. As an example, the UN Sustainable Development Goals have succeeded the Millennium Goals as a vision for the medium-term evolution on the global political level. This dynamism creates an uncertainty to the future development, as the development remains unpredictable and not all events can be anticipated (Waas et al. 2011). For example, parallel developments can mutually influence each other positively and negatively, and progress in one dimension can result in setbacks in another dimension. As a result, one can only determine sustainability progress in retrospect (Meppem and Gill 1998).

The normativity of sustainable development places expectations on the direction of innovation. As Smith et al. 2010 describe it, " the challenge for innovation no longer rests solely in economic potential, but also in the societal changes induced by innovative activity and the consequences of this for environmental and social sustainability" (Smith et al. 2010, p. 437). Moreover, innovators cannot target a single dimension of sustainability in isolation, but have to consider all sustainability dimensions and interrelations (Urmetzer et al. 2018; Clune and Zehnder 2020).

As a result, sustainable development requires innovation directed towards tackling sustainability challenges to a higher extent. Some scholars such as Rauter et al. 2019 therefore define sustainability innovation as new products, services, and processes which result "from a full life-cycle perspective – in less negative environmental and/or increased social impact compared to relevant alternatives and consider the needs of future generations" (Rauter et al. 2019, p. 227).

However, incremental product and process innovations such as automobile catalysts, while considerably improving environmental efficiency, have often been undermined by absolute increases in consumption (Geels et al. 2004; Smith et al. 2010). As a result, they only constitute symptomatic and short-term solutions, often simply shifting the problems from one entity to another (Ehrenfeld 2008; Gaziulusoy 2015).

Instead of such techno-fixes, solving sustainability problems therefore requires to consider the broader context with all the interdependencies and interrelations (Dovers and Handmer 1992; Gaziulusoy 2015; Abson et al. 2017). This relates to the conception of sustainability as a system property rather than a property of system elements in isolation (Clayton and Radcliffe 1996). Specific innovations in form of products, services, or technologies but also organizations or industry sectors cannot be regarded as sustainable on their own, but only when the socio-technical system they are embedded in is sustainable (Sartorius 2006; Smith and Stirling 2010; Gaziulusoy et al. 2013). As a result of the currently unsustainable socio-technical systems, sustainable development calls for a fundamental change, i.e. system innovations or transitions (Smith et al. 2010; Beers and van Mierlo 2017).

3.2
Characteristics of sustainability transitions

Transitions are not determined by technological innovations, but are combinations of change in several aspects of a system including institutions, technologies, economy, infrastructures, patterns of behavior, ecology and cultural values (Rotmans et al. 2001; Elzen and Wieczorek 2005). The change processes in these system dimensions are interconnected, influencing and reinforcing each other (Rotmans et al. 2001), giving transitions a coevolutionary character (Geels and Schot 2010; Geels et al. 2004). This is in contrast to incremental innovation, which are characterized by an evolution of technology with relatively little adaptation of the societal embedding (Elzen and Wieczorek 2005).

Moreover, transitions resolve from the interaction within and between a wide range of actor groups (Geels et al. 2004; Elzen and Wieczorek 2005), including businesses, consumers, scientists, policymakers, social movements, NGOs and special interest groups (Elzen and Wieczorek 2005; Geels and Schot 2010). These actor groups have different views, interests, strategies and resources (Geels 2005). In addition, not all actors profit from transitions. The interactions therefore not only take the form of e.g. commercial transactions, collaboration and learning, but also political negotiations and power struggles (Geels 2005; Hölscher et al. 2018).

According to the multi-level-perspective, transitions come about through the interplay of developments and interactions within and between the three levels that constitute a socio-technical system: niches, regimes and landscape (Geels 2005; Geels and Schot 2007). They can be understood as a nested hierarchy,

with niches embedded within regimes and regimes embedded within landscapes (Geels and Schot 2010).

In this model, the regime represents the dominant existing socio technical system as a context of social structures and a semi-coherent set of rules that guide the behavior of actors (Geels 2002; Schot and Kanger 2018). Such rules can take various forms, e.g. formal rules such as regulations, standards and laws, normative rules such as relationships, values and behavioural norms and cognitive rules, e.g. belief systems, guiding principles and search heuristics (Geels 2005; Geels and Schot 2010). In that way, the rules account for the stability of socio-technical systems (Geels and Schot 2010), e.g. by influencing the research activities of companies (Kemp et al. 1998), but are also reinforced and changed through action and enactment (Geels 2005). They are further stabilized by social networks and infrastructures, e.g. established market structures and dominant technology designs (Geels and Schot 2010), as well as vested interests of incumbent actors (Geels and Kemp 2007), including material aspects such as sunk investments (Geels 2005). Having historically co-evolved (Grin 2010), the rules as well as stable social networks and infrastructures provide strong structuration for actors, making it difficult to deviate (Geels and Schot 2010), thereby creating lock-in mechanisms (Raven et al. 2012). As a result, regimes are dynamically stable, resulting in incremental innovation (Geels 2005) along existing trajectories (Papachristos et al. 2013).

Niches act as 'incubation rooms' (Schot 1998) nurturing the early development (Geels 2005) of radical, path breaking alternatives by protecting them from the pressures of the incumbent regime (Smith et al. 2010), thereby allowing nonconformism (Rotmans and Loorbach 2010). Such niches can have various forms. They can be small market niches (Geels 2005) with particular consumer demands such as strong environmental awareness (Köhler et al. 2019). Niches can also be particular geographical areas like regions (Weber and Truffer 1999) or cultural milieus of early adoption (Smith et al. 2010). They may have the form of technological niches, e.g. targeted policy support (Geels et al. 2017) or experimental projects, with resources provided by public subsidies or private investments (Geels and Schot 2010). They allow to build and grow social networks that support the development of innovation (Geels and Kemp 2007). Moreover, niches provide space for learning processes (Geels 2002) regarding technology, infrastructure (Geels 2005), practices (Rotmans and Loorbach 2010) or institutional requirements (Smith et al. 2010).[3] The sociological structuration in niches is radically different from regimes (Geels et al. 2017), as niches do not follow a specific trajectory, but are rather characterized by a variety of options going in all kinds of directions (Geels 2002). Niche actors often operate

[3] The notion of encouraging learning processes in experimental settings is particularly prevalent among scholars of strategic niche management, which e.g. argue that the sequences of experiments enable recursive learning cycles which in turn generate innovation trajectories (Geels and Raven 2006).

outside or on the fringe of the regime (Geels and Schot 2007) and therefore only have limited power (Raven et al. 2012). The social networks are small and unstable, with actors entering and leaving (Geels and Schot 2010) and sparse interrelations (Schot and Kanger 2018). The rules are diffuse and unclear (Geels 2005) and in constant flux (Schot and Kanger 2018). As a result, niches require high efforts from actors to sustain (Geels and Schot 2010). At the same time, the actors are quite dedicated (Geels and Schot 2007), willing to invest time and money in developing the novelty (Köhler et al. 2019) and more forgiving of possible challenges (Smith et al. 2010).

The landscape forms deep structural gradients of force that influence developments on regime and niche level by making some actions easier (Geels and Schot 2010) while others are more risky, costly and difficult (Raven et al. 2012). The landscape is an exogenous environment that cannot be directly influenced by regime and niche actors (Geels and Kemp 2007), although human activities may change the landscape in the long term, e.g. the multitude of actions and factors that account for urbanization (Geels and Schot 2010).[4] The metaphor does not only relate to the hardness and static nature of a geographic landscape, e.g. mountains, lakes and rivers, but also to dynamic aspects such as rainfall patterns or lightning (Geels and Schot 2007). Correspondingly, change usually takes place quite slowly on the landscape level, such as demographic trends or the climate (Geels 2002), but can also appear as rapid external shocks, e.g. as wars or earthquakes (Geels and Schot 2010).

As long as regimes are stable, niche innovations are likely to be blocked and have little change to break through (Geels and Schot 2010). However, the linkages of regime dimensions can weaken for a short period if internal dynamics lead to tensions or if changes at the landscape level put pressure on the regime (Geels 2002). Regime actors may absorb the pressures or tensions (Papachristos et al. 2013), but in some cases, the destabilization creates a "window of opportunity"(Geels 2002). If niche innovations have developed sufficiently, they may take advantage of such a window, otherwise it will close unexploited, without a transition (Geels and Schot 2010).

Transitions are thus very complex and comprehensive processes (Geels 2005; van den Bosch et al. 2005), which do not come about in a linear fashion (Veldkamp et al. 2009) or mechanically, but are rather crooked (Geels 2005). There is no simple causality in transitions, as there is no simple cause or driver (Geels 2005). Instead, transitions come about through the alignment and mutual reinforcement of processes on each of the three levels (Geels and Schot 2007; Geels et al. 2017). These complex processes can take a long time, spanning a time horizon of 25 to 50 years (Geels and Schot 2010; Rotmans and Loorbach 2010). Transitions processes can be understood as "an intricate web

[4] In that regard, research on "deep transitions" studies the influence of change processes in multiple regimes on the landscape level (see e.g. Schot 2016 and Kanger and Schot 2019).

of fast and slow developments as a result of positive and negative feedback mechanisms" (Rotmans and Loorbach 2010, p. 108), including external events such as the tsunami-induced accident at the Fukushima nuclear power plant which resurrected the political decision to fade-out nuclear energy in Germany. The course of a transition is therefore fraught with a high degree of uncertainty and cannot be predicted or planned in advance (van den Bosch et al. 2005; Sartorius 2006).

Sustainability transitions bring with them further particularities. Sustainable development as a normative concept is highly contested and interpretations of what is considered sustainable vary widely, so different actor groups tend to disagree about the most desirable innovations and pathways for sustainability transitions (Markard et al. 2012; Köhler et al. 2019). As the current development path is unsustainable, sustainability transitions include exnovation, i.e. intentionally fading out unsustainable technologies, practices, infrastructures (Heyen 2016). Regime incumbents, whose advantageous economic position is threatened are thus likely to challenge sustainability transitions (Sartorius 2006; Köhler et al. 2019). Governance and regulatory guidance therefore play a particular role in sustainability transitions (Markard et al. 2012). Public policy can accelerate and slow down change processes through e.g. environmental regulations, standards and innovation policies as well as economic incentives through funds, taxes and subsidies (Kemp et al. 2007; Köhler et al. 2019). Accelerating factors such as political coalitions and civil society pressure underline the context-specific dynamics of sustainability transitions (Geels et al. 2017). This also includes whether actors have developed the capabilities to use such opportunities (WBGU 2011; Köhler et al. 2019).

3.3
Implications for knowledge transfer by regional intermediaries

The characteristics of sustainable development and the particularities of sustainability transitions result in several implications for knowledge transfer.

For instance, the interrelated multidimensionality of sustainable development implies that regional intermediaries aiming to foster sustainable development have to include knowledge bases from different societal subsystems representing the different dimensions, such as described in the quintuple helix innovation model by Carayannis et al. 2012. This model extends the triple helix innovation model by Etzkowitz and Leydesdorff 2000 that represents university-industry-government relations by a fourth helix for the civil society and a fifth for the natural environment (Carayannis et al. 2012). This perspective integrates the ecological dimension as an equivalent component of knowledge production and innovation with the aim to foster sustainable development (Carayannis et al. 2012). An implementation of the quintuple helix model in the organizational structure of a regional intermediary implies an interdisciplinary and transdisci-

plinary approach as the understanding of all helices requires the whole disciplinary spectrum and the involvement of actors from different societal groups in knowledge transfer (Carayannis and Campbell 2019).

Furthermore, the normativity of sustainable development based on the principle of intra- and intergenerational equity implies that regional intermediaries take a normative perspective on innovation. In that regard, actors can build on concepts such as dedicated innovation systems and mission-oriented innovation systems. Dedicated innovation systems explicitly focus on fostering system innovation and accelerating sustainability transitions (Pyka 2017; Schlaile et al. 2017). This results in a particular focus on experimentation and the co-creation of social and technological solutions to overcome path dependencies with multiple stakeholders (Pyka 2017; Urmetzer et al. 2018). Similarly, mission-oriented innovation systems temporarily assemble relevant actors from different sectors with the aim to define, pursue and complete a societal mission, i.e. "an urgent strategic goal that requires transformative systems change directed towards overcoming a wicked societal problem" (Hekkert et al. 2020, p. 76).

The institutional dimension of sustainable development and its evolutionary character, as well as the conflicting interests of stakeholder in sustainability transitions require the implementation of continuously adjusted governance mechanisms in the organizational structure of regional intermediaries. In that regard, transition management presents an approach to organize the change processes towards sustainable development. Transition management distinguishes between four types of governance activities in transitions. First, strategic activities at the level of a societal system with a long time horizon focused on creating alternative futures; second, tactical activities at the level of subsystems build up and break down system structures such as institutions and infrastructure; third, short term operational activities related to everyday decisions changing or recreating system structures; and fourth, reflexive activities with regard to evaluating the existing situation at the different levels and their interrelation (Loorbach and Rotmans 2010). On this basis, transition management aims to direct transitions towards sustainable development by creating transition arenas in which actors from different societal groups cooperate (Rotmans and Loorbach 2010; Köhler et al. 2019).

The interplay of the niches, regime and landscape in sustainability transitions as perceived by the multi-level-perspective shows the importance of regional intermediaries to actively support niche development and regime destabilization. Strategic Niche Management provides an approach for the former by collectively creating, developing and phasing out niches as protected spaces that allow nurturing and experimentation with radical innovations (Geels and Schot 2010; Kemp et al. 1998). It is characterized by articulating a vision, multi-level learning and creating and fostering social networks of advocates (Geels and Raven 2006; Stiles 2020). In addition, the intermediary structure may work to

influence public policy to destabilize the incumbent regime in order for the developed radical innovations to break out of the niche successfully

4
Knowledge in the context of sustainable development

To provide implications regarding the influencing factors for the support of regional intermediaries to sustainable development, this chapter describes the role of knowledge in sustainability transitions and formulates the particularities regarding knowledge transfer.

4.1
Knowledge supporting sustainability transitions

Scholars have identified three types of knowledge as most relevant for sustainability transitions.[5] These are 'system knowledge', 'target' or 'normative knowledge' and 'transformation' or 'transformative knowledge' (ProClim 1997; Abson et al. 2014).

System knowledge refers to the understanding the structures, processes as well as the variabilities and dynamics of the complex socio-technical system in its current status (ProClim 1997; Urmetzer et al. 2018). From a problem-solving perspective, system knowledge comprises an understanding and interpretation of the functioning as well as the root, evolution and possible development of sustainability problems (Wittmayer and Hölscher 2017; Hirsch Hadorn et al. 2011), which includes the ability to separate causes from symptoms (Urmetzer et al. 2020). Such an understanding constitutes a prerequisite for successful innovation activities towards sustainable development (Grunwald 2004). Otherwise, they may have the opposite effect and thus raise further sustainability problems (Nölting et al. 2012).

Normative or target knowledge provides orientation in change processes by showing which future system is desirable (ProClim 1997; Abson et al. 2014). It works twofold. First, it determines and explains the necessity of change and provides visions and formulate specific goals and practices (ProClim 1997; Hirsch Hadorn et al. 2011; Wittmayer and Hölscher 2017). Secondly, it supports steering decisions during the change process by rationally evaluating the current situation and alternative potential developments of the system (ProClim 1997; Abson et al. 2014). As a result, normative knowledge is essential in sustainability transitions so that rationalized recommendations for action are not torn between conflicting goals of stakeholder groups (Urmetzer et al. 2018; Nölting et al. 2012).

Transformative or transformation knowledge and identifies the possible means to bring about the desired change (Hirsch Hadorn et al. 2011), i.e. the knowledge on how the sustainability transition can be shaped (ProClim 1997).

[5] Over time, scholars have complemented the three knowledge types by numerous others, e.g. action knowledge, enabling actors to choose between different options to act, concerning normative, operative and strategic aspects of their specific contexts, and act accordingly Wittmayer and Hölscher 2017.

This includes knowledge on e.g. technical, social, legal and cultural options to change existing practices (Wittmayer and Hölscher 2017) that takes into account the possible effects of institutional prerequisites (ProClim 1997). In that regard, transformative knowledge is required so actors can develop and apply strategies to accelerate sustainability transitions (Nölting et al. 2012; Urmetzer et al. 2018) such as policy interventions, participatory processes, empowerment, education communication (Abson et al. 2014; Urmetzer et al. 2020).

The three knowledge types are interdependent. The change options of transformative knowledge build on system knowledge and normative knowledge (Abson et al. 2014) and therefore depend on the perception of the system and the desired goal (Hirsch Hadorn et al. 2011). Conversely, normative knowledge is influenced by knowledge on the current system and change options (Hirsch Hadorn et al. 2011). Furthermore, the problem interpretation as part of the system knowledge derives from the perception of a desirable target state based on normative knowledge, while the development perspective includes the change options identified with transformative knowledge (Hirsch Hadorn et al. 2011).

4.2
Competencies supporting sustainability transitions

For knowledge to support sustainability transitions and the solution of sustainability challenges, it not only needs to be produced, but also requires to be efficiently integrated into actions (ProClim 1997). This translation is however rather indirect, as action is also influenced by perceptions and attitudes as well as the surrounding conditions (ProClim 1997). To integrate this application perspective, scholars have broadened the scope from knowledge to competences, i.e. "the combination of the individual knowledge, skills and attitudes which enable individuals to perform certain tasks and achieve specific goals" (Blok et al. 2016, p. 2).

Regarding sustainable development, competencies should "enable successful task performance and problem solving with respect to real-world sustainability problems, challenges, and opportunities" (Wiek et al. 2011, p. 204). These transcend traditional technology-oriented skills and include moral aspects and different concepts of thinking that enable actors to address the complexity, uncertainty and risks of change processes (Rieckmann 2012; Blok et al. 2016; Urmetzer et al. 2020). Research in this field has resulted in frameworks for academic programs such as the twelve competencies identified by Rieckmann 2012 or the five competencies introduced by Wiek et al. 2011, which have been translated to the business context, inter alia, by the seven competencies framework developed by Dentoni et al. 2012 and sharpened by Lans et al. 2014. Although conceptual understandings and delineations differ among the frameworks, they largely overlap regarding the key competencies.

Similar to system knowledge, systemic thinking or systems-thinking competence refers to the ability to analyse complex systems and their structure, key components and dynamics across different dimensions (social, environmental, economic, institutional), different disciplines and different scales (local to global) (Wiek et al. 2011; Dentoni et al. 2012; Lans et al. 2014). This analytical capability involves understanding and reflecting upon the interdependency of systems and their subsystems (Dentoni et al. 2012), thereby considering the inertia, feedback loops and cascading effects related to sustainable development (Wiek et al. 2011; Lans et al. 2014). Systems-thinking competence is important to assess the interrelated and interdependent factors which are involved in sustainable development (Blok et al. 2016). It is required to identify intervention points, anticipate future developments and building strategies to shape sustainability transitions (Wiek et al. 2011).

Anticipatory or foresight thinking competence describes the ability to analyse, evaluate and craft visions or narratives of the future, which assess the impact of local and short term decisions on sustainable development at the global scale and in the longer term (Wiek et al. 2011; Dentoni et al. 2012; Lans et al. 2014). This includes skills in creativity, articulating complex matters, recognizing opportunity and balancing local and global as well as short and long term perspectives (Wiek et al. 2011; Lans et al. 2014). Anticipatory competence is important to integrate impact assessment into decision making, e.g. regarding business operations (Blok et al. 2016).

Normative competence refers to sustainable development as a normative concept that describes the world not as it currently is, but as it should be in the future (Lans et al. 2014). It means the ability of multiple stakeholders to collectively apply, negotiate and reconcile sustainability values and principles (Wiek et al. 2011; Lans et al. 2014; Blok et al. 2016). Based on these values, it enables actors to assess and improve the sustainability problems of the socio-technical system in its current and possible future states (Wiek et al. 2011; Dentoni et al. 2012) and to hold actors accountable for their decisions (Lans et al. 2014).

In addition to such competencies that can be derived from the characteristics of sustainable development and sustainability transitions, there are other competencies required for steering the multi-stakeholder processes, which characterize sustainability transitions. Strategic competence, e.g., is the ability to collectively design projects and implement interventions and strategies to accelerate sustainability transitions (Wiek et al. 2011; Dentoni et al. 2012) , including skills in planning, organizing, leading and controlling (Lans et al. 2014). Complementarily, interpersonal competence gives actors the ability to motivate, enable and facilitate collaborative and participatory activities that contribute to sustainable development, which includes skills in communicating, collaborating, empathy and leadership (Wiek et al. 2011; Lans et al. 2014). This collaboration is based on the ability to involve multiple stakeholders and maximize the exchange of ideas and learnings across different groups and disciplines, denoted

by Dentoni et al. 2012 and Lans et al. 2014 as 'embracing diversity and interdisciplinarity'. Taking an individual perspective, action competence then enables actors to take responsibility and actively involve themselves in responsible actions for sustainability transitions (Lans et al. 2014; Blok et al. 2016).

As a more general approach to competencies for sustainability transitions, Schneidewind 2013 introduced the concept of 'transformative literacy' based on the 'environmental literacy' concept of Scholz 2011 to describe "the ability to read and utilize information about societal transformation processes, to accordingly interpret and get actively involved in these processes" (Schneidewind 2013, p. 83). Transformative literacy is formed from the combination of four dimensions, technological, economic, institutional and cultural literacy (Schneidewind 2014). The technological dimension describes the ability to generate and understand technological knowledge and use it to address sustainability challenges (Schneidewind 2013). The economic dimension involves the ability to produce and apply economic knowledge e.g. to evaluate potential technological solutions in economic terms (Schneidewind 2013, 2018). The institutional dimension refers to an understanding of institutions as formal and informal rules that guide interaction and behavior of societal actors (Schneidewind 2014). The cultural dimension describes the understanding for the cultural and value orientations in societies, recognizing that institutional, economic and technological processes are also embedded in cultural environments (Schneidewind 2013).

4.3
Implications for knowledge transfer by regional intermediaries

When aiming to foster sustainable development, regional intermediaries should support the generation and transfer of system knowledge, normative knowledge and transformative knowledge. In addition, they should support actors in obtaining the competencies required to accelerate sustainability transitions: system thinking, anticipatory, normative competence as key competencies supplemented by strategic management, interpersonal and action competence. The specific knowledge types and competencies for sustainability transitions give implications for the organization of knowledge transfer by regional intermediaries.

As system knowledge is descriptive, it is subject to constant change, following the dynamic development of the observed system (Urmetzer et al. 2018). Furthermore, the dynamic interrelations in socio-technical systems are difficult to address separately and disciplinary (Abson et al. 2017). As a result, system knowledge is expected to be highly specialized and dispersed across different knowledge bases, which only have few interfaces (Abson et al. 2017; Urmetzer et al. 2018). Moreover, as it requires a considerable intellectual effort to start thinking in systems rather than in linear cause-and-effect relations, system

knowledge can be quite sticky which increases the effort for transfer (Urmetzer et al. 2018).

Normative knowledge is highly specific to the local context, as norms and values regarding sustainable development of actors are shaped by their institutional context (Urmetzer et al. 2018). While formal institutions such as laws are transparent, informal and subject rules can be expected to remain tacit, creating a barrier for the transfer outside the specific institutional context (Urmetzer et al. 2018). The exchange of such tacit knowledge depends largely on trust-based relationships between stakeholders (Schienstock 2005). In addition, the cognitive distances of knowledge carriers as well as conflicting visions and strategies impede the creation, diffusion and use of normative knowledge (Urmetzer et al. 2018; Urmetzer et al. 2020).

Transformative knowledge is also quite local, as the concrete measures regarding sustainability transitions have to be negotiated and agreed upon at the regional and local scales (Urmetzer et al. 2018). Moreover, in order to change the practices that result in sustainability problems, the influencing institutions have to be changed (Urmetzer et al. 2018). Thus, carriers of transformative knowledge have to reconsider and revise inherited values and assumptions, which makes transformative knowledge extremely sticky (Urmetzer et al. 2018; Urmetzer et al. 2020).

Regional intermediaries have to take an interdisciplinary approach required to develop an understanding of the complex interplay of diverse influencing factors in systems (Abson et al. 2017). Moreover, for the three interdependent knowledge types to be socially robust and not only theoretically applicable, transdisciplinary collaborations are required (ProClim 1997; Kanning and Meyer 2019). This also relates to the multi-stakeholder-approach pursued by 'embracing diversity and interdisciplinarity' and enabled by interpersonal competence. In addition, this underlines the importance of including knowledge bases from different social groups as e.g. in the quintuple helix innovation model, further supported by the multidimensional approach of system thinking competence. The importance of interpersonal and strategic management competence underlines the role of governance mechanisms in these collaborations.

Furthermore, the context specificity of normative and transformative knowledge highlights the need to adopt a local or regional perspective in the knowledge transfer for sustainable development, providing opportunities for regional intermediaries. Dedicated Innovation Systems are a model which explicitly incorporates the co-creation of normative and transformative knowledge by all relevant actors (Pyka 2017).

5
Conclusions

Based on the literature review, this paper was able to formulate several implications of the characteristics of sustainable development and sustainability transitions and the related types of knowledge and competencies for the organization of knowledge transfer by regional intermediaries. Overall, regional intermediaries may foster sustainable development by establishing structures and processes that support the generation and transfer of system knowledge, normative knowledge and transformative knowledge for contributions to sustainable development, and help actors to obtain the competencies for accelerating sustainability transitions (system thinking, anticipatory, normative competence as key competencies supplemented by strategic management, interpersonal and action competence). The specific implications can be summarized as follows:

1. Knowledge transfer for sustainable development requires an interdisciplinary as well as a transdisciplinary approach to account for sustainable development as a system property and a holistic understanding of system knowledge and system thinking competence.
2. To generate and apply knowledge required for sustainability transitions, knowledge transfer structures should involve multiple stakeholders from all societal subsystems of the quintuple helix, including science, government, industry, civil society and natural environment.
3. Normativity of sustainability and interpretative tendencies based on conflicting interests requires the stakeholders integrated in the organization structure of regional intermediaries to collectively articulate their goals and visions regarding sustainable development, thereby building normative competencies. In that regard, they can be inspired by concepts such as dedicated or mission-oriented innovation systems.
4. With the help of public policy and governance mechanism, the intermediary structure may create niches for radical innovations to grow while working to destabilize the incumbent regime for a successful break-out.
5. Goals and visions should have a local and regional reference as well as an individual perspective to take into account the specific institutional context and allow the successful negotiation of actions and responsibilities.

The implications presented in this paper only derive from existing literature and need to be verified by empirical analysis. The strong emphasis on the normativity of sustainable development opens up the question whether an explicit focus of regional intermediaries on sustainable development increases the sustainability impact of the incited and supported innovation activities.

6
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Die Forschungsgruppe sofia fragt nach der Funktionsfähigkeit von Institutionen und den Möglichkeiten, durch veränderte institutionelle Rahmenbedingungen staatliche oder gesellschaftliche Steuerungsziele zu erreichen. Dem sofia-Team gehören Ökonomen und Juristen ebenso an wie Politikwissenschaftler, Soziologen, Ingenieure und Naturwissenschaftler (-innen).

Der sozialwissenschaftliche Begriff der "Institution" bestimmt das gemeinsame methodische Herangehen: Institutionen sind danach "Spielregeln", die sich Gruppen oder Individuen geben, um bestimmte Ziele zu erreichen. Institutionen umfassen damit sowohl rechtliche Regelwerke als auch Regeln in Organisationen (z.B. im Unternehmen, im Verein oder in einer Partei) bis hin zu stillschweigenden Konventionen.

Die Funktionsfähigkeit von Institutionen ist abhängig von der Interessenlage der Beteiligten. Die Kernfragen lauten: "Welche Faktoren bestimmen die Motivationslage und welche Entscheidungsregeln bestimmen das Handeln?" Parallel sind die Ziele der Institution zu betrachten: "Wie lassen sich diese so erreichen, dass zugleich die Eigenmotivation der Beteiligten möglichst hoch bleibt?" Eine derart aufgebaute *Institutionenanalyse* ermöglicht ein besseres Verständnis des Zusammenspiels der Akteure, aber auch der Steuerungsbeiträge der verschiedenen institutionellen Rahmenbedingungen. Dies gilt nicht nur für den status quo, sondern auch für mögliche alternative Gestaltungen der Rahmenbedingungen.

Sonderforschungsgruppe Institutionenanalyse
h_da - FB GS / SuK, Haardtring 100, 64295 Darmstadt
Fon +49 6151 1638735, Fax +49 6151 1638470
info@sofia-darmstadt.de www.sofia-darmstadt.de

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Sonderforschungsgruppe Institutionenanalyse
h_da - FB GS / SuK, Haardtring 100, 64295 Darmstadt
Fon +49 6151 168735, Fax +49 6151 168470
info@sofia-darmstadt.de www.sofia-darmstadt.de