Original Research Paper

Opening up the black box of learning-by-doing in sustainability transitions

Katrien Van Poeck[a,*], Leif Östman[b], Thomas Block[c]

[a] Ghent University, Department of Political Sciences, Centre for Sustainable Development, Ghent, Poel 16, B-9000 Belgium
[b] Uppsala University, Department of Education, Uppsala, Box 2136, 750 02, Sweden
[c] Ghent University, Department of Political Sciences, Centre for Sustainable Development, Ghent, Poel 16, B-9000, Belgium

A B S T R A C T

In the face of persistent socio-ecological problems that prove hard to tackle with existing routines, the transition towards a more sustainable world is often described as a matter of 'learning by doing'. Despite omnipresent appeals to 'learning' in sustainability transition studies, an exploratory review of literature shows that there is a lack of conceptual clarity on the topic. Furthermore, empirical research on learning in transition initiatives is rare. This article presents an analytical framework that facilitates theoretical and empirical research on learning in sustainability transitions. Pragmatist educational scholarship, in particular Dewey's transactional perspective, provides useful inspiration for analytical tools that allow to open-up the black box of learning in sustainability transitions. Focusing on the intrapersonal, interpersonal, institutional and material factors that influence learning and on how the mechanism of 'privileging' steers learning outcomes, this framework allows to investigate whether and, if so, how learning actually takes place in transition initiatives.

1. Introduction

Faced with persistent socio-ecological problems diverse actors all over the world are engaged in initiatives aimed at fostering sustainability transitions (ST): fundamental changes at the level of complex socio-technical systems like the energy, mobility, housing or agro-food system (Geels and Schot, 2007). STs are long-term processes that change deeply anchored structures, practices and cultures, resulting in a profound transformation of a system in multiple dimensions – technology, economy, actors involved, regulation, science, production patterns, consumer preferences, policies, infrastructures, markets, power relations, discourses on problem definitions and solutions, institutions, cultural meanings, etc. (Paredis, 2013). Existing decision-making institutions and routines often prove unable to adequately tackle persistent and complex, so-called 'wicked' sustainability problems (Rittel and Webber, 1973). Hence, appeals have been made to *learning* as a vital means of creatively transforming unsustainable regimes. The transition towards a more sustainable world has thus repeatedly been described as a matter of 'learning by doing' and 'doing by learning' (Loorbach, 2007). Yet, despite omnipresent references to the importance of learning in research literature and policy discourses on STs the notion of learning and its role in relation to transitions is poorly conceptualised and empirical research on how learning actually takes place in concrete ST initiatives is rare. The aim of this article is to address these gaps by developing and presenting an analytical framework that can advance much-needed research on learning in STs.

In the next section, we present an overview and critical analysis of how learning is addressed in ST scholarship drawing on an

---

* Corresponding author.
  E-mail addresses: katrien.vanpoeck@ugent.be (K. Van Poeck), leif.ostman@edu.uu.se (L. Östman), thomas.block@ugent.be (T. Block).

exploratory review of literature in this field. Then, we contribute to overcoming the identified lack of conceptual clarity and of a thorough empirical knowledge base on learning in STs by presenting an analytical framework that serves to facilitate theoretical and empirical research. We subsequently describe the framework's theoretical background, i.e. pragmatist educational scholarship and operationalise it drawing on Dewey's transactional analytical perspective. We conclude by discussing the framework's potential for future research.

2. Learning in sustainability transitions: an exploratory literature review

In order to obtain an overview of how learning is addressed in existing research on STs we conducted an exploratory review of literature. Using the search terms 'learning' AND 'transition' as well as 'learning' AND 'sustainability' we collected numerous publications and weeded out non-relevant papers. In order to minimise the risk of excluding important contributions, we performed an additional search for articles about 'learning' in *Environmental Innovation and Societal Transitions* and explored the reference lists of all collected papers looking for relevant sources. Out of the thus obtained collection we selected a sample of 20 publications published between 2003 and 2018. The selection was guided by the principle of maximum variation, resulting in a collection covering different authors, a variety of national/local contexts, research methods, theoretical backgrounds and focus of analysis (e.g. the sustainability problems and practices/learning settings under study). We systematically analysed the publications with the help of QSR NVivo software. The questions guiding our analysis were: Why is learning regarded important or necessary?; What is learned or should be learned?; How is the learning process described?; Where does learning take place?; How is learning conceptualised?; Which learning theories are used?; and What are blind spots in the available literature? The result of our analysis is summarised in Table 1[1]. The Codebook in Appendix A shows the coding 'tree' that was developed during our analysis, starting from a limited number of initial codes associated to our analytical questions.

2.1. Why is learning important for sustainability transitions?

In the reviewed literature, learning is consistently put forward as vital for ST. Several arguments are used to underpin this claim.

2.1.1. A more sustainable world
Very often, authors directly relate the need for learning to the realisation of sustainable development. Several of them argue for learning as a vital means for fostering sustainability because of the *complexity* of this challenge. 'The more complex the innovation challenges', Beers et al. (2016, n.p.) argue, 'the more important the associated learning. Sustainability transitions arguably rank among the most complex innovation challenges'. Nevertheless, some have high expectations as to the potential of learning to foster STs. Domènech et al. (2015, p. 28), for instance, linearly connect learning processes to regime transformation. They study 'the learning dynamics and scaling-up opportunities behind the ongoing emergence of a new urban water regime' and argue that 'learning processes determine the direction and speed of the transition.' Similarly, Xia and Pahl-Wostl (2012, p. 62) argue for triple-loop learning, which 'implies the dominance of a new management paradigm and a corresponding transformation in the rest of the regime shaped by the paradigm'. Others are more modest. Ingram (2018 p.119), for example, who investigates how knowledge development can contribute to the successful growth and emergence of niches 'and potentially regime transformation', or Schot and Geels (2008) who argue that learning indeed contributes to the successful emergence of niches, a crucial yet insufficient factor for bringing about regime shifts.

2.1.2. Societal intelligence
Learning is also considered important for building 'societal intelligence' for STs (Brown et al., 2003 p. 313). Collective consciousness and a collective change in the perceptions of solutions requires that knowledge, innovations and information travel among the members of the society, they argue. Thus, learning is seen as a prerequisite for the diffusion, dissemination and up-scaling of ideas, practices and experiments, for niche aggregation through knowledge sharing and accumulation and for developing shared visions and plans. The need to build societal intelligence is also connected to the specificity of STs, dealing with sustainability issues which 'are significantly harmful and urgent, highly complex, and cannot be solved by simple remedies' (Wiek and Kay, 2015 p. 30). Furthermore, 'they do not fall in any specific topical area, discipline, or expertise' so that tackling them requires 'collective problem-solving capacity'. Multiple actors need to be involved in 'continuous evaluation and adaption' (Boon and Bakker, 2016 p.182), as they often do not know beforehand what their interests exactly are or how various policies will affect them or the proposed transition. Desirable transition pathways need to be articulated through 'trial-and-error'. This is something that needs to be learned collectively, along the way.

2.1.3. Better governance
Relatedly, learning is also considered important for better governance of STs. Arguments raised are that learning among stakeholders with different perspectives and information enhances decision-making and promotes the legitimacy of governance solutions, that it helps to manage resistance towards transitions, yields insights into the desirability of policy outcomes and distributes the

---

[1] For reasons of readability, we did not include all the references to the analysed sources in this text (only when specific ideas or statements are quoted) but refer to Table 1 for an overview.

Table 1

Summary of the literature review.

Why is learning important for sustainability transitions?	
Realising a more sustainable world	
Sustainability (general)	Schot and Geels, 2008; Xia and Pahl-Wostl, 2012; Johannessen and Hahn, 2013; Wiek and Kay, 2015; Domènech et al., 2015; Benson et al., 2016; Beers et al., 2016; Larsson and Holmberg, 2018; Sol et al., 2018; Ingram, 2018; Bocken et al., 2018 forthcoming
Dealing with the complexity of STs	Beers et al., 2016; Bocken et al.,2018 forthcoming
Realising regime change	Xia and Pahl-Wostl, 2012; Domènech et al., 2015
Creating conditions for regime change	Schot and Geels, 2008; Ingram, 2018
Building societal intelligence	
Dissemination of ideas, practices and experiments	Brown et al., 2003; Domènech et al., 2015; Ingram, 2018
Niche aggregation	*Borghei and Magnusson, 2018* forthcoming
Developing shared visions and plans	Benson et al., 2016
Collective problem-solving	Wiek and Kay, 2015
Better governance of STs	
Enhance decision-making	Loeber et al., 2007; Benson et al., 2016
Promote the legitimacy of solutions	Benson et al., 2016
Manage resistance	*Bocken et al., 2018* forthcoming
Distribute responsibility	Boon and Bakker, 2016
Creativity	
Developing new knowledge	Benson et al., 2016; Ingram, 2018
Questioning the taken for granted	Loeber et al., 2007; Brown et al., 2003; Forrest and Wiek, 2014; Larsson and Holmberg, 2018; Sol et al., 2018; Ingram, 2018
What is learned or should be learned in relation to sustainability transitions?	
Practical learning outcomes	
Change agency	Sol et al., 2018
Habits, behaviour, technologies practices	Brown et al., 2003; Beers et al., 2016; Godelnik, 2017; Ingram, 2018; Sol et al., 2018; Larsson and Holmberg, 2018
Regime shifts	Xia and Pahl-Wostl, 2012
Innovative solutions	Brown et al., 2003; Loeber et al., 2007; Wiek and Kay, 2015; Beers et al., 2016; Ingram, 2018; Sol et al., 2018; Larsson and Holmberg, 2018; Singer-Brodowski et al., 2018
Relational learning outcomes	
Networks and other social arrangements	Brown et al., 2003; Benson et al., 2016; Larsson and Holmberg, 2018
Trust and respect	Beers et al., 2016; Sol et al., 2018
Conceptual learning outcomes	
Acquiring knowledge	Benson et al., 2016
Sharing knowledge	Domènech et al., 2015; Borghei and Magnusson, 2018 forthcoming
Integrating knowledge	Singer-Brodowski et al., 2018; Larsson and Holmberg, 2018
Accumulating knowledge	Brown et al., 2003; Johannessen and Hahn, 2013; Domènech et al., 2015; Beers et al., 2016; Ingram, 2018; Singer-Brodowski et al., 2018; Larsson and Holmberg, 2018; Borghei and Magnusson, 2018 forthcoming
Values and norms	Loeber et al., 2007; Brown et al., 2003; Johannessen and Hahn, 2013; Van Poeck et al., 2017; Sol et al., 2018; Ingram, 2018; Larsson and Holmberg, 2018
Commitment	Beers et al., 2016; Sol et al., 2018
Visions	Brown et al., 2003; Larsson and Holmberg, 2018),
Mindsets	Godelnik, 2017
Identities	Brown et al., 2003; Loeber et al., 2007; Ingram, 2018; Singer-Brodowski et al., 2018
Conceptual space	Brown et al., 2003; Larsson and Holmberg, 2018
Creativity	Van Poeck et al., 2017; Ingram, 2018
Critical thinking and reflection	Brown et al., 2003; Johannessen and Hahn, 2013; Benson et al., 2016; Van Poeck et al., 2017; Singer-Brodowski et al., 2018; Sol et al., 2018; Larsson and Holmberg, 2018
Dismantling the taken for granted	Loeber et al., 2007; Godelnik, 2017; Van Poeck et al., 2017; Ingram, 2018; Larsson and Holmberg, 2018
Multi-perspectivism	Van Poeck et al., 2017; Larsson and Holmberg, 2018
Reframing	Benson et al., 2016; Sol et al., 2018; Ingram, 2018
Agreement	Benson et al., 2016
Congruency	Loeber et al., 2007
Guidance in uncertainty	Larsson and Holmberg, 2018
How does learning take shape in the context of sustainability transitions?	
Learning settings	
Variety of learning settings: governance networks, grassroots initiatives, bounded socio-technical experiments, real-world laboratories, transition arenas, universities	Brown et al., 2003; Forrest and Wiek, 2014; Wiek and Kay, 2015; Van Poeck et al., 2017; Godelnik, 2017; Singer-Brodowski et al., 2018; Larsson and Holmberg, 2018; Sol et al., 2018
Specificity of learning settings:	
Uncertainty and complexity	Boon and Bakker, 2016; Bocken et al., 2018 forthcoming
Variety of actors	Boon and Bakker, 2016; Singer-Brodowski et al., 2018; Sol et al., 2018

Table 1 (*continued*)

Normativity	Domènech et al., 2015; Boon and Bakker, 2016; Singer-Brodowski et al., 2018; Bocken et al., 2018 forthcoming
Focus on intervention	Wiek and Kay, 2015; Domènech et al., 2015; Singer-Brodowski et al., 2018; Bocken et al., 2018 forthcoming
Traditional steering inadequate	Loeber et al., 2007; Forrest and Wiek, 2014; Domènech et al., 2015; Sol et al., 2018
Focus on experimentation	Boon and Bakker, 2016; Larsson and Holmberg, 2018; Singer-Brodowski et al., 2018; Bocken et al., 2018 forthcoming
Enabling conditions	
Interaction	Brown et al., 2003; Loeber et al., 2007; Johannessen and Hahn, 2013; Domènech et al., 2015; Boon and Bakker, 2016; Beers et al., 2016; Van Poeck et al., 2017; Sol et al., 2018; Larsson and Holmberg, 2018; van Mierlo and Beers, 2018; Borghei and Magnusson, 2018 forthcoming
Space for pluralism and dissonance	Loeber et al., 2007; Johannessen and Hahn, 2013; Boon and Bakker, 2016; Beers et al., 2016; Van Poeck et al., 2017; Sol et al., 2018; Ingram, 2018; Larsson and Holmberg, 2018; Bocken et al., 2018 forthcoming
Experience	Loeber et al., 2007; Domènech et al., 2015; Benson et al., 2016; Godelnik, 2017; Larsson and Holmberg, 2018; Ingram, 2018
Experimentation	Domènech et al., 2015; Bocken et al., 2018 forthcoming
Openness and flexibility	Brown et al., 2003; Johannessen and Hahn, 2013; Van Poeck et al., 2017; Sol et al., 2018; Larsson and Holmberg, 2018
Impediments	
Difficulties to deal with pluralism and disagreement	Beers et al., 2016; Van Poeck et al., 2017; Ingram, 2018
Insufficient opportunities to explore the issues at stake	Wiek and Kay, 2015; Benson et al., 2016; Van Poeck et al., 2017
Blind spots	
Lack of conceptual clarity	Boon and Bakker, 2016; Benson et al., 2016; Beers et al., 2016; Singer-Brodowski et al., 2018; Sol et al., 2018; van Mierlo and Beers, 2018
Weak empirical knowledge base	Brown et al., 2013; Benson et al., 2016; Ingram, 2018; Larsson and Holmberg, 2018; van Mierlo and Beers, 2018

responsibility for sustainability governance beyond only governments, including also other stakeholders. In this respect, Loeber et al. (2007 p. 84), argue that governing sustainable development implies a need for learning because 'it is an essentially *contestable* concept, in the sense that no authoritative universally valid definition can be formulated. There is no way of determining what is "really sustainable" other than through processes of collective and contextual deliberation and mutual learning'.

2.1.4. Creativity

Finally, several authors interestingly argue for learning because STs require creativity. As 'old routines no longer suffice in light of wicked sustainability challenges' (Sol et al., 2018 p.3), we need to acquire 'new perspectives, skills, competencies, practices and develop new concepts of [our] own role' (Singer-Brodowski et al., 2018 p. 23). This need for creativity, it is argued, moves beyond the necessity of developing new knowledge but also involves questioning the taken for granted and creating 'a conceptual space' where prevalent perspectives, norms, values and institutions can be changed (Brown et al., 2003 p.311). This implies re-evaluating and adapting long-term goals, purposes and strategies, challenging business-as-usual practices that reinforce the lock-in of systems and developing fundamentally different practices of technical and social innovation. After all, Loeber et al. (2007 p.84) emphasise, sustainable development is a 'revolutionary concept' and the system innovation it demands implies an opening-up of existing, un-sustainable routines, rules, values and assumptions. Learning, then, requires 'a critical scrutiny of things that are usually taken for granted, in such a way that their historically grown self-evidence ("path-dependency") is challenged' and should be understood as 'reflection on the theories, beliefs and assumptions that underlie action'.

2.2. What is learned or should be learned in relation to sustainability transitions?

As Beers et al. (2016) explain, literature on learning in STs distinguishes conceptual and relational learning outcomes. In our review, we additionally found several authors referring to practical learning outcomes.

2.2.1. Practical learning outcomes

Attention for practical outcomes aligns well with the emphasis on learning as a means for making our world more sustainable (see 2.1.1). Learning, then, is assumed to contribute to some form of sustainability change agency, as well as to more sustainable habits, behaviour, technologies, practices or even regimes. Remarkably, several authors highlight innovation and varied forms of 'newness' – in particular innovative solutions for sustainability challenges – as an important (desired) outcome of learning in the context of STs. So, in line with emphasis on the need for creativity as one of the main arguments why learning is vital for STs (see 2.1), learning processes are obviously also assumed to result in outcomes that meet that need, i.e. the co-creation of new or changed knowledge, actions, networks, arrangements, solutions, systems, etc. For example: 'By incorporating a transformative approach, the learning environment could provide guidance in uncertain environments, fostering exploration of new possibilities rather than exploitation of old certainties … including through elements of future state visioning … systems thinking … and bridging the gap between present

and future through processes of learning, leadership and creation' (Larsson and Holmberg, 2018).

2.2.2. Relational learning outcomes

Much less frequently mentioned are relational learning outcomes. In this respect, authors describe how learning can result in the development of networks and other social arrangements and in building trust and respect.

2.2.3. Conceptual learning outcomes

Conceptual learning outcomes by far receive most attention and, as our codebook (Appendix A) shows, authors refer to a wide variety of such outcomes. Perhaps not surprisingly, knowledge is mentioned most frequently. Authors write about how learning can contribute to not only acquiring knowledge but also sharing, integrating and especially accumulating knowledge. The latter is related to the importance of building collective, societal intelligence (see 2.1). Several authors stress that knowledge is never neutral in the context of STs. 'Where knowledge is invested within a given practice', Ingram (2018 p.130) argues, 'it should be seen as "at stake," indicating the significant costs associated with giving it up and acquiring diff ;erent knowledge'. Hence, considerable attention is paid to learning outcomes such as values and norms, commitment, visions, mindsets, identities, etc. Also notable are repeated references to how learning can contribute to open-up 'conceptual space' (Brown et al., 2003, p. 311) and broaden 'the scope of how challenges and problems are framed and defined' (Larsson and Holmberg, 2018 p. 4413). Attention for learning outcomes like creativity, critical thinking and reflection, dismantling the taken for granted, multi-perspectivism and reframing is in line with the argument that learning is important for fostering creativity and questioning the status quo (see 2.1). However, besides creating space and openness learning is also expected to contribute to coming to some kind of closure, for instance agreement, congruency or guidance in uncertainty.

2.3. How does learning take shape in the context of sustainability transitions?

2.3.1. Learning settings

In the reviewed literature, learning is widely approached as a multi-level phenomenon entailing both an individual and a collective dimension. A variety of settings are described where people learn in the context of STs. These are mainly informal learning settings such as governance networks, grassroots initiatives, bounded socio-technical experiments, real-world laboratories and transition arenas. Also universities, however, receive attention as a setting where students learn in relation to STs. Several authors emphasise the *specificity* of these learning settings. Often, they are characterised by uncertainty and complexity. They gather a variety of actors (e.g. entrepreneurs, civil servants, educational institutes, NGO's, citizens, researchers, civil society actors, politicians, etc.) that are brought together by a sustainability challenge as a common matter of concern. Yet, these actors do not necessarily share the same ideas, interests and preferences as to how to deal with this issue. On the contrary, they face conflicting values, dilemmas and a lack of agreement. As the focus of the described learning settings is on intervention, they are repeatedly described as spaces for 'learning by doing' and 'doing by learning'. Yet, due to the aforementioned complexity, uncertainty and normativity, these interventions cannot easily be managed. Traditional command and control or top-down steering often prove inadequate. Hence, many of the described learning environments are oriented towards experimentation and exploration. Larsson and Holmberg (2018) describe such 'lab approaches' as 'guided processes built upon empowerment where space is created for the learners to explore, experiment, and test solutions' (p. 4413) and where considerable time is allocated to exploring issues, i.e. for 'staying in the question' (p. 4418).

2.3.2. Enabling conditions and impediments

Enabling conditions and impediments for learning identified in the literature are related to the specificity of these learning processes. One of the most frequently mentioned conditions that facilitate learning is interaction, which is considered vital for sharing and exchanging knowledge, information, meanings, values, interests, narratives, practices, etc. In complex, uncertain and normative contexts like STs, this involves deliberation among a wide range of stakeholders who might hold different meanings, beliefs and interests. This aligns well with a second frequently described enabling condition for learning in STs: Space for pluralism and dissonance. Authors argue that 'mutual differences can be an important resource in the context of complex societal problems' (Beers et al., 2016) which should be used 'as opportunities for learning and improvement' (Bocken et al., 2018 forthcoming). Ingram (2018 p.132). interestingly refers to the importance of 'boundary work' in this respect. The great diversity that typically exists at the boundary or interface between two systems, she argues, has high potential for innovation, creativity and improvement through mutual learning opportunities since it is 'through creative boundary processes or "continually breaking new edge" … that radical innovation emerges following negotiation and reinterpretation of knowledge at boundaries'. What also receives substantial attention, in line with the abovementioned focus learning by doing, is how learning in STs is facilitated through experience. Learning is said to result from offering people the opportunity to engage with concrete, 'real-world' sustainability issues and a space to explore them, try-out solutions, tinker with assumptions, fail, try anew, etc. Openness and flexibility are considered vital to make this possible. Conditions that impede learning are much less frequently mentioned but, if so, mainly concern difficulties to deal with pluralism and disagreement – e.g. conflicts and 'agenda wars' (Beers et al., 2016), a lack of mutual understanding and a lack of space for enacting disagreement – as well as insufficient opportunities to explore the issues at stake.

2.4. Blind spots in literature

We conclude this section with a critical analysis of the reviewed literature. Scrutinising the papers on blind spots in the literature

we identified important theoretical and empirical research gaps.

2.4.1. Lack of conceptual clarity

A striking observation is the lack of conceptual clarity on learning in relation to STs. In several publications, authors do explicitly refer to learning theories to underpin their work., e.g. theories of social learning, scholarship on organisational learning (in particular on single-loop and double-loop learning) and, to a lesser extent, experience-based learning. Yet, not all authors apply learning theories and others do it only superficially. This results in conceptual haziness. In particular, many articles struggle with ambiguity regarding the relation between learning and societal transformation. They fail to present a clear, consistent understanding of the relation and distinction between 'learning' and the changes in society that may be the result of it. Some examples. Several authors treat both elements as synonyms, e.g. Boon and Bakker (2016 p.184) who write that 'policymaking *is regarded as* social learning' (emphasis added). Others take for granted that societal change is the result of *learning*, thereby ignoring other potential causes. E.g. Xia and Pahl-Wostl (2012 p.162) 'claim that a regime starts to transition when double-loop learning … takes place' and build their analysis on the assumption that 'a regime [is] transformed when triple-loop learning is prevalent in all structure components'. Reversely, Domènech et al. (2015 p.37) see the lack of societal change as a result of the *absence* of learning: 'no water quality standards for greywater reuse have been approved yet by any competent authority in Catalonia or Spain which suggests that social learning processes still need to take place at this level'. Due to the lack of conceptual clarity and the confusion of the process and outcomes of learning, the complexity of the relation between learning and societal change is insufficiently acknowledged.

Remarkably, this theoretical gap is also mentioned *within* several of the analysed papers (see sources in Table 1). So, following van Mierlo and Beers, 2018, we can conclude that 'while many transitions scholars underscore the importance of learning for both understanding and governance of sustainability transitions … the associated learning processes have hardly been conceptualised, discussed and elaborated within the field' apart from notable exceptions (e.g. Beers et al., 2016) and that 'well-established research fields related to learning are broadly ignored or loosely applied'. In a somewhat different yet related research area, similar conclusions are drawn by Reed et al. (2010, n.p.). They conducted a literature review on social learning in natural resource management and found that the concept is defined so vaguely and some definitions are so broad that they could encompass almost *any* social process. Frequently, social learning is confused with the conditions or methods necessary to facilitate the process or with its potential outcomes and there is often little distinction made between individual and social learning. 'This lack of conceptual clarity', they argue, 'has limited our capacity to assess whether social learning has occurred, and if so, what kind of learning has taken place, to what extent, between whom, when, and how'. The latter could serve as summary of our own findings regarding empirical blind spots.

2.4.2. Weak empirical knowledge base

Indeed, the rather weak empirical knowledge base for progressing our understanding of learning in the context of STs emerged from our analysis as a second major research gap. Fifteen years after Brown et al. (2013, p. 294) formulated this diagnose, it is still the case that 'with a few exceptions, little systematic study has been done on defining the learning processes in the course of implementation of experiments, monitoring them, assessing their societal impacts, or examining the conditions under which learning occurs (or not) and by what mechanisms'. We did encounter some exceptional examples of thorough empirical studies on learning processes in the context of STs, like the article of Beers et al. (2016) who investigate the influence of interaction patterns on learning outcomes or Ingram's (2018) detailed analysis of the complex interplay between the knowledge systems of the permaculture niche and the mainstream agricultural regime. However, many other empirical research contributions do not convincingly reveal *that*, *what* and *how* people are learning in practices striving for STs. Regularly, strong claims are made, e.g. about how learning leads to a wider horizon of possibilities (Larsson and Holmberg, 2018), to policy change (Xia and Pahl-Wostl, 2012), to attitudinal change (Benson et al., 2016) or change agency (Sol et al., 2018), without sufficient substantiation or convincing empirical evidence. At best, evidence shows that change has taken place but it is too easily taken for granted that this is the outcome of *learning* and not of other potential, equally plausible factors (e.g. 'the attention from a high-ranking politician' in Xia and Pahl-Wostl's (2012, p. 71) case study). Furthermore, it often remains unclear *what* exactly people are learning. Sol et al. (2018), for instance, emphasise the importance of 'reframing' but do not provide any empirical examples of how sustainability issues are reframed. Thus, the content of learning remains black boxed. And the same goes for the learning process, i.e. *how* the (assumed) learning takes shape. There are many general – sometimes abstract – references to conditions that enable learning (see 2.3), but empirical evidence of which elements and mechanisms influence learning and in which direction is very rare.

At a more concrete level, several authors explicitly mention varied blind spots that require further empirical investigation in order to progress scholarship on learning in STs (see sources in Table 1), e.g.: detailed studies that can deepen our insight in the process of learning in STs, investigations that illuminating the role of e.g. knowledge or the learning environment in this process, analyses of the impact and importance of the many conditions that are assumed to facilitate learning, studies that monitor the effectiveness of learning practices or assess if, when and how learning outcomes are conducive for STs, longitudinal studies and comparative case studies aimed at the validation of findings in different contexts.

2.4.3. The need for a suitable analytical framework

These conceptual and empirical research gaps are closely interrelated. Due to the lack of conceptual clarity, the process and outcomes of learning in STs are not sufficiently operationalised, neither theoretically nor analytically, to allow for detailed empirical analysis (see also Reed et al., 2010; Beers et al., 2016). All the same, the lack of a substantial empirical knowledge base impedes conceptualisation and understanding of learning in STs. Hence, what is utmost needed in order to progress the state of the art of research on learning in the context of STs is a suitable analytical framework that enables empirical analyses and further theory

development. In the remainder of this article we introduce such a framework drawing on theory developed within the field of educational research.

3. An analytical framework for empirical analysis and theory development

Out of our review of literature, we can distil the following major research challenges: gaining insight in…

1 the relation between learning processes and the realisation of societal transformation;
2 the conditions under which learning can contribute to creativity;
3 how and what people learn from interaction, in particular in a context of pluralism and dissonance;
4 how and what people learn from experiences and experimentation.

As we will show, work done in the pragmatist tradition of educational research has great potential to address these challenges. In the subsequent paragraphs we explain how it offers useful theoretical background and a suitable analytical lens.

3.1. Theoretical background: pragmatist educational theory

Pragmatist educational theory and in particular John Dewey's work offers fruitful theoretical inspiration to progress scholarship on learning in STs. His theorisation conceptualisation of education and key concepts in his work on education in relation to democracy and experience (Dewey, 1916/1997; Dewey, 1934/2005; Dewey, 1938/2015) provide valuable theoretical resources. The scope of this article does not allow us to elaborate each of these concepts in detail, so we describe them briefly and add references to Dewey's original writings, hoping to trigger the reader's interest to explore them in more depth and apply them to future research on learning in STs.

3.1.1. Learning in relation to societal transformation

Dewey's theory of experience and education focuses on the continuous, simultaneous and reciprocal transformation of the self and the world and is hence well suited for the study of processes of societal change as also learning processes – and vice versa. Interaction between persons and their environment is central in this theory. Basically, it is an understanding of learning in relation to intervention in an environment. It starts from the assumption that humans continuously and actively adapt to and thereby change their environment (Dewey, 1916/1997; 1934/2005; 1938/2015) and that the best way to learn about a situation, is to try to transform it. In his influential work on 'Democracy and Education', Dewey (1916/1997) writes that education has an important social function – i.e. assuring the social continuity of life through creating a common world – but also that democracy, understood as 'a mode of associated living' (Dewey, 1916/1997, p. 87), holds strong educative potential. It is the very process of living together, he argues, that educates. 'It enlarges and enlightens experience; it stimulates and enriches imagination; it creates responsibility for accuracy and vividness of statement and thought' (Dewey, 1916/1997, p. 6).

Vital for a better understanding of learning in relation to societal transformation, is thus to find ways to trace the trajectories of simultaneous and reciprocal transformation of persons and the world and to identify and describe the factors and mechanisms that affect this.

3.1.2. Learning and creativity

Dewey's (1916/1997) writings about the (re)creation of habits, and particularly how he understands habits as expressions of growth, can inform investigations of the creative potential of learning in STs. For him, the goal of education is growth. Learning is what happens when experiences result in a growing, more developed and specific repertoire for action, i.e. better ways of co-ordinating actions to the environment. This is always seen in relation to a purpose which is unfolding through encounters between persons and the world. Important here is that growth should not be understood as a static end that is accomplished as soon as pre-set outcomes are achieved. This would be 'ungrowth' (Dewey, 1916/1997, p. 42). Growth, for Dewey, *is* the end, it does not *have* an end. This crucial difference reflects his creative approach to learning. Movement toward fixed goals diminishes the space for creativity, downplays the power of learners, fails to cope with novel situations and overemphasises the pursuit of automatic skill at the expense of personal perception. This is problematic since creative learning requires the formation of active habits, of capacities that can be freely applied to new aims. A habit, Dewey explains, is thus not the same as a routine. Routines are rigid and inflexible, repeated similar responses. As we become unaware of them and do not control them, they do not allow us to respond to changing environments. Habits, in contrast, are characterised by meaningful thought, observation and reflection, which are prerequisites for their potential varied and elastic use in accordance with self-selected desires and purposes. They bring about the power to control the environment and to modify actions based on the results of prior experiences. This also involves imagination. Imaginative experiences of possibilities that contrast with actual conditions, Dewey (1934/2005) argues, open-up a space for creativity or, as Garrison et al. (2015) call it, educative moments as a result of critical and creative inquiry.

Gaining insight in conditions for growth and the (trans)formation of habits and in how educative moments emerge and are handled can contribute to a better understanding of the creative potential of learning practices.

3.1.3. Learning from interaction, pluralism and dissonance

Dewey's (1916/1997, p. 5) claim that 'all communication (and hence all genuine social life) is educative' provides an interesting

perspective on investigating how learning emerges from interaction in a context of pluralism and dissonance. For him, meaning-making is inherently a social activity which involves contact, communication and deliberation and in which diversity and conflicts are not only inevitable but also productive. Deliberation, for Dewey, is dealing with incommensurable values, not with the purpose of making them commensurable, but to uncover conflict in its full scope and bearing and create something (Garrison et al., 2015). Pluralism and dissonance within interactions are thus approached as a precious resource for learning, i.e. as a driver for growth. The 'more numerous and more varied points of contact', the 'greater diversity of stimuli to which an individual has to respond' and the more variation in action (Dewey, 1916/1997 p.87). This liberates powers which remain suppressed in practices that shut out divergence and conflict. Therefore, Dewey (Dewey, 1916/1997, p. 305) argues, 'a democratic society must, in consistency with its ideal, allow for intellectual freedom', a mental attitude that requires a leeway for exploration, experimentation, application, etc. Knowledge, experiences and skills should not be treated as something static that could be taught as a finished product. Instead, learning should be the result of a co-operative enterprise that creates 'social intelligence' Dewey 1938/2015, p. 72), not a dictation. However, this does not mean that established knowledge, methods and rules of conduct cannot have any directive value. 'We may reject [it] as the *end* of education', Dewey (Dewey, 1938/2015, p. 23) argues, 'and thereby only emphasize its importance as a *means*', i.e. as an object for inquiry (see 3.1.4).

Crucial for investigating how and what people learn from interaction, is to analyse how meaning is collectively created and transformed in and through interaction, to identify and describe the factors and mechanisms influencing this process and to determine its outcomes.

3.1.4. Learning from experience and experimentation

Dewey (1938/2015) views learning as a continuous process of reconstruction of experience that comes about through encounters between a person and his/her environment. Yet, he argues, 'the belief that all genuine education comes about through experience does not mean that all experiences are genuinely or equally educative … For some experiences are mis-educative.' (Dewey, 1938/2015, p. 25). In order to be educative, experience must lead out into an expanding world of facts, information and ideas, i.e. growth (see 3.1.2). 'Learning by doing' (Dewey, 1916/1997), then, is not a linear and instrumental process of learning to do the right things – based on 'right' knowledge – but 'a matter of doing and undergoing the consequences of doing' (Dewey, 1916/1997, p. 279) in which *thinking* plays a vital role: accurately and deliberately creating 'connections between what is done and its consequences' (Dewey, 1916/1997, p. 151). Learning is the result of a confrontation with a problematic situation that gives rise to inquiry: examining and reflecting upon means and ends, testing ideas and hypotheses by the consequences which they produce when they are acted upon. Inquiry thus leads to judgement based on careful observation and a wide range of information an learning emerges from experimentation in unfamiliar situations that arouse 'an active quest for information and for production of new ideas' and are as such 'the stimulus to thinking' (Dewey, 1938/2015, p. 79). Dewey compares learning based on inquiry to the experimental method of science: It requires careful observation, reflective review and approaches ideas *as ideas,* as hypotheses instead of as final truths. Treating ideas as truths takes away any reason for scrupulous examination (inquiry) whereas hypotheses must be continuously tested and revised.

Researching how and what people learn from experiences and experimentation requires an analysis of the process and outcomes of an inquiry induced by the confrontation with problematic situations, i.e. the factors and mechanisms that shape the joint meaning-making as well as the resulting expanding world of facts, information and ideas.

3.1.5. A pragmatist conceptualisation of learning in sustainability transitions

In sum, from a Deweyan perspective, learning in the context of STs can be conceptualised as a process in which persons and the world transform simultaneously and reciprocally through interaction and experimentation with sustainability challenges. Experiencing problematic situations regarding how to tackle these challenges, they engage in inquiry. Learning, then, is what happens when the meaning-making emerging from this inquiry results in a growing, more developed and specific repertoire for action, i.e. better ways of coordinating actions to the environment in relation to a purpose. According to Dewey's democratic educational ideal, this purpose is not imposed on the learners but takes shape through a process of social intelligence, based on intellectual freedom. In this perspective, learning is not a merely cognitive activity but also involves value judgement, emotions, practical skills, commitment, identity, etc.

3.2. Analytical perspective: a transactional approach

Investigating whether such learning has occurred, and if so, to what extent, between whom, when, how and what people learned requires analytical tools that allow to open-up the black box of learning processes and to trace connections between process and outcomes. There is a growing body of research literature that reports on the effectiveness of (mainly formal) learning in terms of desirable outcomes. What is lacking, however, is empirical research on the learning process. Whereas evaluation studies are typically based on statistical research that measures, monitors and compares people's knowledge, values, motivation, behaviour, etc. before and after (or with and without) an intervention, an inquiry into the black box of how such changes come about requires in-depth, qualitative studies based on observation of concrete practices. Here, too, Dewey's work provides inspiration. His transactional perspective (Dewey and Bentley, 1949/1991) that has been applied to the domain of didactic research (e.g. Öhman and Östman, 2007; Östman, 2010) is particularly useful for research on learning in STs. It acknowledges the high complexity of the object of study and allows to link the learning process and its outcomes without conflating them.

3.2.1. Transaction

Dewey's theory of learning from experience is based on the principles of continuity and interaction (see 3.1.1). These however, should not be understood in a causal, linear and mechanistic way. Instead, a 'transactional' perspective (Dewey and Bentley, 1949/1991) approaches people and their surroundings as mutually interdependent. They transform *continuously* and *reciprocally*, i.e. 'in transaction'. 'An experience', Dewey (1938/2015, p. 43) argues, 'is always what it is because of a transaction taking place between an individual and … his [sic] environment'. Human actions change the environment and shifts of activity happen in response to changing conditions. Learning takes place through this continuous process of doing and undergoing the consequences of acts (Öhman and Östman, 2007). This is what Dewey (1938/2015 p.35) calls continuity: 'every experience enacted and undergone modifies the one who acts and undergoes, while this modification affects, whether we wish it or not, the quality of subsequent experiences. For it is a somewhat different person who enters into them.' Learning is thus understood as a process that takes place through encounters between a person and an environment (social and material). The learning outcomes emerging from these encounters are not seen as static cognitive properties to achieve but as something that is dynamically made and transformed in and by action.

Dewey and Bentley's transactional perspective is not intended to be a theory that provides general and universal explanations but a method of investigation with the ambition to foster further inquiry (Öhman and Östman, 2007). We draw on it for developing an analytical framework for research on learning in STs hoping that the findings emerging from its application may eventually contribute to an empirically grounded theoretical knowledge base.

3.2.2. Factors influencing learning

From a transactional perspective, analysing learning processes and outcomes requires explicating the relationships between human action and the context in which it occurs (Wertsch, 1998). Cognitivist and sociocultural researchers have debated the advantages and disadvantages of different learning theories. The main critique of cognitivist research is that it fails to account for the institutional and interpersonal influence on learning, e.g. how cultural tools and interpersonal interaction mediate learning (Ivarsson et al., 2002). The critique of sociocultural research is that the effect of intrapersonal elements (e.g. individuals' earlier acquired knowledge, values, etc.) is overlooked (Hodkinson et al., 2007). Another issue that has surfaced in this discussion and that is particularly relevant for our focus on learning in STs, is the lack of consideration of how the material world influences learning and thus deserves more attention in educational theory (Sorensen, 2009).

Taking into account these arguments, we propose an analytical framework that investigates learning in STs as a process in which a dynamic interplay between varied factors shapes specific outcomes:

1 **intrapersonal** factors: the participants' existing knowledge, previous experiences, opinions, ideas, emotions, routines…
2 **interpersonal** factors, i.e. the social interactions between the persons involved in a particular situation: communication, dialogue, negotiation, deliberation…
3 **institutional** factors, i.e. the influence of elements beyond the specific interactions in a concrete situation: narratives, cultural traditions, discourses, epistemological beliefs, world views…
4 **material** factors: artefacts, the natural environment, infrastructures, technologies, the body…

As separate elements, these factors are recognised as important aspects of learning in STs (see also 2.2 and 2.3.2) and have been empirically investigated. Godelnik, 2017 analysis of how students learn about the sharing economy, for instance, pays attention to the intra-personal factor of students' earlier experiences. Beers et al. (2016) investigated how interaction patterns, an interpersonal factor, shape learning outcomes. Ingram, 2018 focus on the interplay between niche and regime knowledge systems is an example of a detailed analysis of an institutional factor. And Jalasi (2018) addresses material factors when analysing how people learn through engaging with improved cook stoves. What is lacking and important for gaining a nuanced, in-depth understanding of the complexity of learning in STs, is to move on to investigating the *dynamic interplay* between all these factors and how that affects the learning process and outcomes.

3.2.3. Tracing connections between learning process and outcomes

In order to trace the connections between the learning process influenced by these factors and the outcomes of it, we propose to focus the analysis on the 'privileging' process. Wertsch (1998) introduced this term to investigate how actions (practical and conversational) in learning processes communicate which knowledge, skills, values etc. are valid and which are not in a given situation. This affects what is taken into account and what is not and thereby governs learning in a certain direction. Certain meanings, questions, artefacts, material objects, bodily movements etc. emerge as reasonable while others are ignored or disregarded. Privileging thus directs learning in a certain direction and towards certain outcomes. Hence, when analysing the mechanisms of learning we need to look at how the interplay between different factors (intrapersonal, inter-personal, institutional and material) influences privileging.

This demands sophisticated analytical methods that allow operationalisation for empirical investigations. Here, we do not have to start from scratch. Inspiration can be drawn from educational researchers who have developed didactical analytical methods inspired by Dewey's transactional perspective and applied them for empirical studies, mainly in science and environmental education. Practical Epistemology Analysis (Wickman and Östman, 2002), for instance, enables a 'high-resolution' analysis (Östman, 2010, p. 83) of how meaning is created in learning practices. Transactional Argumentation Analysis (Rudsberg et al., 2013) reveals how people learn from deliberative discussions. Epistemological Move Analysis (Lidar et al., 2006) and Political Move Analysis (Van Poeck and Östman, 2018) allow to investigate the impact of interventions (of participants, facilitators, teachers…) on the direction of

learning. These methods can be further developed, combined and provide inspiration for the creation of new methods in order to develop a suitable analytical toolbox for empirical analyses of learning in STs that allow to create knowledge on the factors that influence learning and, of equal importance, the mechanism of *how* they do so. This interest is not only driven by scientific motivations but also by a practical professional perspective. Without this knowledge practitioners are left with the black box problem, ignorant about how to handle crucial elements that influence learning in view of desired outcomes.

4. Conclusion

Drawing on an exploratory review of literature, we identified two interrelated research gaps on learning in STs: A lack of conceptual clarity and of a thorough empirical knowledge base. We developed an analytical framework that serves to facilitate empirical analyses and further theory development. Research that delivers knowledge on the factors and mechanism that influence learning processes and outcomes is much-needed in order to progress the state of the art of scholarship on learning in the context of STs. What is particularly needed, is deeper insight in the role, place, potential and limits of learning in relation to societal transformation, i.c. STs. The latter is utmost ambitious and the theoretical and analytical challenges involved demand sophisticated, large-scale and long-term research. The existing body of literature on learning in STs offers a wide variety of interesting pathways that can and should be further explored. Due to the rather weak empirical evidence base, many of the claims made regarding conditions and outcomes of learning in STs require further investigation and hypothesis testing. Because of the complexity of the object of study this involves a lot of empirical work based on in-situ investigations across diverse contexts and with a longitudinal perspective (see also 2.4.2). Beers et al.'s (2016) and Ingram, 2018 analyses, both addressing one particular factor that influences learning, are illuminating examples of what such an in-depth analysis entails and show the valuable contribution it can make to understanding the complex and nuanced dynamics of learning in the context of STs.

While we stress the importance of this endeavour and wrote this article hoping to facilitate it, we want to conclude with a call to remain modest. Indeed, learning has an important role to play in view of fostering STs (see 2.1). But we also acknowledge educational theorists' (e.g. Säfström, 2011; Masschelein and Simons, 2013) nuanced criticism of an al too linear, instrumental perspective on the relation between learning and the solution of social and political problems. Furthermore, translating complex, contested and wicked sustainability problems into 'simple' learning solutions fails to recognise the complex and far-reaching character of STs. Some researchers seem to take for granted that learning in niche practices brings about regime change (see 2.4.1). Yet, as the multi-level perspective on STs (Geels, 2011) shows, successful niche innovations are necessary yet insufficient to foster a ST. Beyond that, it is imperative that pressure is put on the dominant regime, that internal contradictions of the latter are revealed or enforced, that creative ways are found to overcome lock-in and path dependency, and that the power struggles that go with all this are taken seriously. Not every (small) change in niches will have an effect at the regime level. Not all local and participatory innovations and experiments have the potential to disrupt the dominant regime. A prerequisite for that is that the taken for granted is questioned by showing that something fundamentally different is also possible. Important, then, is to investigate what happens in learning settings (e.g. how a sustainability problem and possible solutions is understood, how this transforms through the learning process, what is thereby taken into account, 'privileged', or not) in the perspective of how this *prepares the terrain* for societal transformation, and which kind of changes thus become more probable than others. Our hope is that the framework we introduced can help to avoid naive perspectives on the relation between learning and systemic societal transformation and deliver insights into how learning *enables or constrains* certain regime transformations and opens up *possibilities* for challenging the unsustainable status quo and taken for granted structures, cultures and practices.

Acknowledgements

Appendix A. NVivo codebook

Name	Sources[a]	References
blind spots	**6**	**8**
methodological blind spots	12	19
empirical blind spots	17	37
theoretical blind spots	21	54
conditions for learning	**2**	**3**
conditions related to facilitation	2	3
clear expectations	1	1
feedback	1	2
conditions related to individuals	6	12
change agents	1	1
commitment	5	6
intellectual entrepreneurship	1	4
ownership	1	1
conditions related to relations and interaction	16	49

boundary work	1	2
collective meaning-making	1	1
common interest	1	2
conflict	1	1
critical dialogue	3	4
dissonance, pluralism	11	17
equality	1	1
interaction	10	15
reciprocity	1	1
trust	4	5
conditions related to the setting	17	47
encounter	1	1
experience	6	7
experimentation	3	10
exposure	1	1
flexibility	1	2
hypothesis testing	1	1
motivational factors	2	3
openness	6	10
reflexivity	2	4
reframing	1	2
safety	3	3
self-assessment	1	1
self-reflection	1	1
tolerance for uncertainty	1	1
drivers for learning	4	33
crisis, urgency	2	21
interaction	3	3
new information	1	2
definitions, conceptions of learning	**15**	**36**
impediments for learning	**1**	**1**
agenda wars	1	1
conflict	1	1
familiarity	1	1
lack of mutual understanding	1	1
no space for disagreement	1	3
strong top-down steering	2	2
technicality	1	1
too little time for study	2	5
learning content, outcomes	**2**	**14**
conceptual outcomes	23	113
change in understanding	4	4
cognitive change	1	1
commitment	3	3
competencies	4	8
comprehending complexity	1	1
conceptual space	4	4
congruency, consensus, agreement	2	5
creativity	2	3
critical thinking	2	2
dismantling taken for granted	6	6
exploring different perspectives	2	6
facts	1	1
guidance in uncertainty	1	2
knowledge	13	33
accumulation of knowledge	8	10
acquisition of knowledge	1	2
knowledge integration	3	3
knowledge sharing	2	3
knowledge system	1	3
not neutral	3	4
mindset	1	1
motivation	1	1
norms and values	8	11
reflection	6	6
reflexivity	2	2
reframing	3	5
resilience	1	1
roles, identities	4	4
visions	2	2
practical outcomes	14	34
action	1	1
change agency	1	1
change in behaviour	1	1

decision	1	1
habit	1	1
innovation, solutions	9	16
new forms of activity, practice	6	7
regime change	3	4
technologies	2	2
relational outcomes	5	14
networks	2	4
respect	1	1
social arrangements	2	2
trust	2	4
learning methods	**2**	**9**
learning setting	**0**	**0**
BSTE	1	2
governance networks	1	2
grassroots sustainability initiative	1	3
real-world laboratories	4	5
specificity of the learning setting	12	34
transition arena	1	1
university	3	5
learning theories	**14**	**30**
links with our analytical framework	**9**	**9**
educative moments	3	3
environing	3	4
factors influencing learning	13	19
institutional factors	7	15
interpersonal factors	6	13
intrapersonal factors	4	4
physical factors	3	3
in situ analyses	3	5
inquiry	7	9
privileging	2	2
problematic situation	1	1
relation learning - change	17	42
transaction	13	16
need for learning	**5**	**9**
better governance	5	7
deliberation on contestable concept	1	1
enhanced decision-making	1	1
legitimacy	1	1
managing resistance	1	1
policy change	2	3
building societal intelligence	10	20
adaptive capacity	1	2
diffusion of ideas, practices, experiments	5	9
explore complex, uncertain, contested sustainability issues	4	6
shared vision	1	1
change	6	12
newness, creativity	8	16
making knowledge practical, action-oriented	1	3
new knowledge	2	2
question the taken for granted	5	8
sustainability	14	20
dealing with uncertainty, complexity	2	2
regime change	5	8
solving sustainability problems	3	3
sustainability change agents	2	2
scale of learning	**1**	**1**
collective learning	11	16
interpersonal learning	1	1
organisational learning	2	2
policy-oriented learning	1	1
social learning	4	6
individual learning	9	11
multi-level learning	2	3

References

Beers, P.J., van Mierlo, B., Hoes, A.C., 2016. Toward an integrative perspective on social learning in system innovation initiatives. Ecol. Soc. 21 (1), 33.

Benson, D., Lorenzoni, I., Cook, H., 2016. Evaluating social learning in England flood risk management: an 'individual-community interaction' perspective. Environ. Sci. Policy 55, 326–334.

Bocken, N.M.P., Schuit, C.S.C., Kraaijenhagen, C., 2018. Experimenting with a circular business model: Lessons from eight cases. *Environ. Innov. Soc. Transit.* 28, 79–95.
Boon, W.P.C., Bakker, S., 2016. Learning to shield – policy learning in socio-technical transitions. Environ. Innov. Soc. Transit. 18, 181–200.
Borghei, B.B., Magnusson, T., 2018. Niche aggregation through cumulative learning: A study of multiple electric bus projects. Environ. Innov. Soc. Transit. 28, 108–121.
Brown, H.S., Vergragt, P., Green, K., Berchicci, L., 2003. Learning for sustainability transition through bounded socio-technical experiments in personal mobility. Technol. Anal. Strateg. Manag. 15 (3), 291–315.
Dewey, J., Bentley, A.F., 1949/1991. Knowing and the Known. Southern Illinois University Press, Carbondale.
Dewey, J., 1916/1997. Democracy and Education. An Introduction Into the Philosophy of Education. The Free Press, New York.
Dewey, J., 1934/2005. Art As Experience. Perigee. New York. .
Dewey, J., 1938/2015. Experience and Education. Free Press, New York/London/Toronto/Sydney/New Delhi.
Domènech, L., March, H., Vallès, M., Saurí, D., 2015. Learning processes during regime shifts: empirical evidence from the diffusion of greywater recycling in Spain. Environ. Innov. Soc. Transit. 15, 26–41.
Forrest, N., Wiek, A., 2014. Learning from success—toward evidence-informed sustainability transitions in communities. Environ. Innov. Soc. Transit. 12, 66–88.
Garrison, J., Östman, L., Håkansson, M., 2015. The creative use of companion values in environmental education and education for sustainable development: exploring the educative moment. Environ. Educ. Res. 21 (2), 183–204.
Geels, F., 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms. Environ. Innov. Soc. Transit. 1, 24–40.
Geels, F., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36, 399–417.
Godelnik, R., 2017. Millennials and the sharing economy: lessons from a 'buynothing new, share everything month' project. Environ. Innov. Soc. Transit. 23, 40–52.
Hodkinson, P., Biesta, G., James, D., 2007. Understanding learning cultures. Educ. Rev. 59 (4), 415–427.
Ingram, J., 2018. Agricultural transition: Niche and regime knowledge systems' boundary dynamics. Environ. Innov. Soc. Transit. 26, 117–135.
Ivarsson, J., Schoultz, J., Säljö, R., 2002. Map reading versus mind reading. Revisiting children's understanding of the shape of the earth. In: Limon, M., Mason, L. (Eds.), Reconsidering Conceptual Change: Issues in Theory and Practice. Kluwer, Amsterdam, pp. 77–99.
Jalasi, E.M., 2018. Investigating and Expanding Learning Across Activity System Boundaries in Improved Cook Stove Innovation Diffusion and Adoption in Malawi. Thesis (PhD). Rhodes University, Grahamstown.
Johannessen, Å., Hahn, T., 2013. Social learning towards a more adaptive paradigm? Reducing flood risk in Kristianstad municipality, Sweden. Global Environ. Change 23, 372–381.
Larsson, J., Holmberg, J., 2018. Learning while creating value for sustainability transitions: the case of Challenge Lab at Chalmers University of Technology. J. Clean. Prod. 172, 4411–4420.
Lidar, M., Lundquist, E., Östman, L., 2006. Teaching and learning in the science classroom. Sci. Educ. 90 (1), 148–163.
Loeber, A., van Mierlo, B., Grin, J., Leeuwis, C., 2007. The practical value of theory: conceptualising learning in the pursuit of a sustainable development. In: Wals, A.E.J. (Ed.), Social Learning Towards A Sustainable World. Wageningen Academic Publishers, Wageningen, pp. pp. 83–97.
Loorbach, D., 2007. Transition Management, New Mode of Governance for Sustainable Development. International Books, Utrecht.
Masschelein, J., Simons, M., 2013. In Defence of the School: A Public Issue. E-ducation, Culture and Society Publishers, Leuven.
Öhman, J., Östman, L., 2007. Continuity and change in moral meaning-making—a transactional approach. J. Moral Educ. 36 (2), 151–168.
Östman, L., 2010. Education for sustainable development and normativity: a transactional analysis of moral meaning-making and companion meanings in classroom communication. Environ. Educ. Res. 16 (1), 75–93.
Paredis, E., 2013. A Winding Road. Transition Management, Policy Change and the Search for Sustainable Development. Thesis (PhD). Ghent University, Gh Social learning towards a sustainable world. ent.
Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C., Stringer, L.C., 2010. What is social learning? Ecol. Soc. 15 (4) r1.
Rittel, H.W., Webber, M.W., 1973. Dilemmas in a general theory of planning. Policy Sci. 4, 155–169.
Rudsberg, K., Öhman, J., Östman, L., 2013. Analysing students' learning in classroom discussions about socio-scientific issues. Sci. Educ. 97 (4), 594–620.
Säfström, C.A., 2011. Rethinking emancipation, rethinking education. Stud. Philos. Educ. 30 (2), 199–209.
Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technol. Anal. Strateg. Manag. 20 (5), 537–554.
Singer-Brodowski, M., Beevroft, R., Parodi, O., 2018. Learning in real-world laboratories: a systematic impulse for discussion. Gaia 27 (S1), 23–27.
Sol, J., van der Wal, M.M., Beers, P.J., Wals, A.E.J., 2018. Reframing the future: the role of reflexivity in governance networks in sustainability transitions. Environ. Educ. Res. 24 (9), 1383–1405 pre-published online.
Sorensen, E., 2009. The Materiality of Learning – Technology and Knowledge in Educational Practice. Cambridge University Press, New York.
van Mierlo, B., Beers, P.J., 2018. Understanding and governing learning in sustainability transitions: A review. Environmental Innovation and Societal Transitions. It is available online: https://www.sciencedirect.com/science/article/pii/S2210422417301983?via%3Dihub, in press.
Van Poeck, K., Östman, L., 2018. Creating space for 'the political' in environmental and sustainability education practice: a Political move Analysis of educators' actions. Environ. Educ. Res. 24 (9), 1406–1423.
Van Poeck, K., Vandenabeele, J., Goeminne, G., 2017. Making climate change public? A dramaturgically inspired case-study of learning through transition management. Int. J. Glob. Warm. 12 (3/4), 366–385.
Wertsch, J., 1998. Mind As Action. Oxford University Press, New York.
Wickman, P.O., Östman, L., 2002. Learning as discourse change: a sociocultural mechanism. Sci. Educ. 86, 601–623.
Wiek, A., Kay, B., 2015. Learning while transforming: solution-oriented learning for urban sustainability in Phoenix, Arizona. Curr. Opin. Environ. Sustain. 16, 29–36.
Xia, C., Pahl-Wostl, C., 2012. Understanding the development of flood management in the middle Yangtze River. Environ. Innov. Soc. Transit. 5, 60–75.