Original Research Paper

Understanding and governing learning in sustainability transitions: A review

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ABSTRACT

Many transitions scholars underscore the importance of learning in sustainability transitions, but the associated learning processes have hardly been conceptualised. The diverse, well-established research fields related to learning are broadly ignored or loosely applied. In this paper, we systematically explore four interesting learning traditions in terms of their value for gaining an in-depth understanding of learning in sustainability transitions and their relevance for fostering learning, by connecting them to key features of transitions. The selected learning traditions from different disciplinary backgrounds provide valuable insights. None of them sufficiently addresses the complexity of transitions. They include, however, a diversity of relevant learning contexts. We conclude that they have value for investigating new areas such as learning in socio-techno-logical regimes and in later phases of a transition, while enlightening forms of learning that have not yet been fully recognised in transition studies, such as superficial learning, unlearning, and learning to resist change.

1. Introduction

An unfortunate gap exists between diverse learning traditions and sustainability transition studies. Although many transitions scholars underscore the importance of learning for both the understanding and the governance of sustainability transitions (Loorbach and Rotmans, 2006; Raven et al., 2008), the associated learning processes have hardly been conceptualised, discussed, and elaborated within the field.

A specific transition perspective on learning has been developed: by sharing experiences with a novelty in practice in multiple pilot projects, knowledge is aggregated and generic rules are developed that influence the organisation of later pilot projects (Geels and Deuten, 2006). Other learning, for instance between niches and regimes and within regimes, gets very little attention and is hardly investigated empirically.

Moreover, the diverse, well-established research fields related to learning are broadly ignored or loosely applied. Early strategic niche management for example, elaborated learning as the articulation of needs, problems, and possibilities in experiments with a sustainable novelty and implicitly used notions of organisational learning (Kemp et al., 1998). In this paper, we therefore investigate the extent to which and how conceptualisations of learning relate to the specifics of sustainability transitions and what their value could be for these transitions. For instance, how do perspectives on learning in homogeneous groups mesh with transition processes that straddle social levels and multiple constituencies? For learning theories to be salient to transition studies, they need to be meaningful in the light of key characteristics of sustainability transitions.

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In this paper, we systematically explore four well-established learning traditions on their value for gaining an in-depth understanding of learning in transitions and their relevance for fostering learning, because 1) ideas from diverse traditions appear in sustainability transitions studies and 2) multiple types of learning processes can be expected to take place in transitions, given their complexity. In this way, we aim to bridge the gap between learning approaches and sustainability transition thinking. We hope to inspire transition scholars to consider their perspective on learning more explicitly and to make better use of valuable insights from established traditions. Likewise, we aim to inspire learning scholars to make a greater effort to contribute to sustainability transition studies by acknowledging and adding to the basic ideas on which these studies build.

2. Methodology

2.1. Identifying learning traditions

Well-known learning concepts and theories appear in diverse scientific fields with different meanings depending on the context in which they are used. Instead of conducting a rigorous conceptual analysis showing the diversity of meanings and the development of, and the relations between, concepts, the focus of our analysis is on well-established research fields. By identifying their basic ideas, rather than highlighting the crossovers, we can acknowledge their unique features and hence their specific potential value for transition studies.

To analyse well-established research fields, we selected a few scholarly learning traditions that exhibit the characteristics of a research programme in the sense of Lakatos (1968–1969). According to Lakatos, any scientific research programme consists of a hard core that cannot be rejected within that programme. Research programmes are successful when they 1) develop *auxiliary hypotheses* and *touchstone theories* that save the theoretical hard core from refutation by inconsistent empirical evidence and 2) become increasingly complicated to more accurately simulate reality. In other words, we can speak of a research programme when scholars recognise it as a tradition with a more or less stable core and when its progress is documented – it has to exhibit some conceptual and empirical development beyond being often used. This is considered to be the case if review articles exist, because these entail the acknowledgement of a body of research as a tradition, document its basic tenets, and often describe the progress in the field.

In order to show the potential value of well-established learning traditions and connect them to transition thinking, we selected four out of a wealth of some tens of research programmes. These four programmes: 1) are analytical and descriptive rather than normative; 2) consider learning as a process among a plurality of persons or actors; 3) display broad differences between them, basically because they have unique disciplinary backgrounds. The following traditions were thus selected:

- Collaborative learning (educational sciences)
- Organisational learning (management studies)
- Social learning in natural resource management (complex system thinking)
- Interactive learning in the learning economy (institutional economics)

Completeness in the sense of acknowledging all potentially relevant traditions would be a sheer impossibility. We mention a few interesting ones in Section 4, hoping to inspire others to undertake a similar effort to analyse their value for the transitions context.

The analytical level of the traditions varies as a consequence of our methodology. We turned to the key sources of the most influential scholars to analyse the core features of each research programme.

2.2. Systematic assessment

The learning traditions are expected to both reveal and conceal aspects of sustainability transitions (compare Framing: Goffman, 1974). Their value for understanding learning in transitions is systematically assessed by examining their core features in the light of salient dimensions of transitions.

In a review of the emerging field of sustainability transitions, Markard et al. (2012) identify transition management, strategic niche management, the multi-level perspective, and technological innovation systems as the four most prominent frameworks. Sustainability transitions are basically "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012, p. 956). The two key concepts connecting the four strands are *socio-technological regime* and *niche*, which are the basis of the core model of transition studies: the multi-level perspective. For a description of these key concepts see Box 1.

In transition studies, learning is usually assumed to take place in an early phase of transitions in and around niches or, from a slightly different angle, a technological innovation system (see among others Geels and Raven, 2006; Hekkert et al., 2007; Hoogma et al., 2002; Loorbach and Rotmans, 2006; Smith and Raven, 2012; van Mierlo, 2012).

In the most elaborated perspective on learning in transitions specifically, learning is seen to take place at different places in different phases (see Fig. 1):

- among actors located within a local experiment, pilot project, or initiative ('Local practices' in Fig. 1);
- between local experiments;
- from local experiments to an emerging niche or field ('Cosmopolitan level' in Fig. 1); and
- in interactions between experiments and niche (once the niche has formed).

In this ideal-typical model, learning is the translation of experiences in local projects into general knowledge, rules, and norms, thus creating knowledge flows between these places (Geels and Deuten, 2006; Geels and Raven, 2006; Smith and Raven, 2012). It requires interaction between actors and dedicated knowledge aggregation activities by intermediary actors. Scientific accounts of learning by and among incumbent actors, of learning that is not conducive to sustainability transitions, and of unlearning are largely absent from the domain of transition studies. Also, conflicts, which abound in transitions, are hardly addressed as a potential source of learning (Cuppen et al., 2016).

Box 1
The regime and niche concepts

A socio-technological regime is the configuration of technology, knowledge, infrastructure, symbolic values, and role division that has emerged around social practices (Rip and Kemp, 1998; Tukker et al., 2008). Hence, it is regarded as the existing, dominant system that fulfils a specific societal function, like the provision of energy or food. A regime is stabilised through various self-reinforcing or lock-in mechanisms. Geels (2004) discerns three kinds of stabilising mechanisms. First, the rules in the system, including cognitive heuristics, normative rules, and formal regulations, provide stability because they guide actions and perceptions. They are deep structures on which knowledgeable actors draw in their actions and therefore provide the action context (Giddens, 1984). In their actions, they also adapt or redefine these structures. Given that rules are aligned within a system, it is hardly possible to change one rule without altering others. Second, the mutual dependence between actors contributes to the stability of a system. Once networks have formed around a policy issue, market, or programme, the actions of the actors involved (including the suppliers, traders, and buyers from a value chain) become increasingly intertwined. In such networks, actors can become locked into their relationships, thus blocking new ideas from outside and discouraging other potentially fruitful collaborations (Klein Woolthuis et al., 2005). Finally, long lifetimes of the material components of a system add to its stability, as well as the investments sunk in infrastructure and the complementarities of material components of technologies. These mechanisms explain why regime changes tend to follow certain pathways and consist of predominantly incremental innovation.

Niches are protected spaces of small application domains in which radical, novel ideas and incipient social and technical innovations have the opportunity to mature. In this process, new ideas evolve about the meaning and value of these innovations, as well as user preferences, desirable product development, and the needed policy and infrastructure. The development and specification of these ideas are called learning processes. Although the novelties in the niches essentially compete with the regime, interactions between empowered niches and regimes are essential for sustainability transitions to ensue (Beers and van Mierlo, 2017).
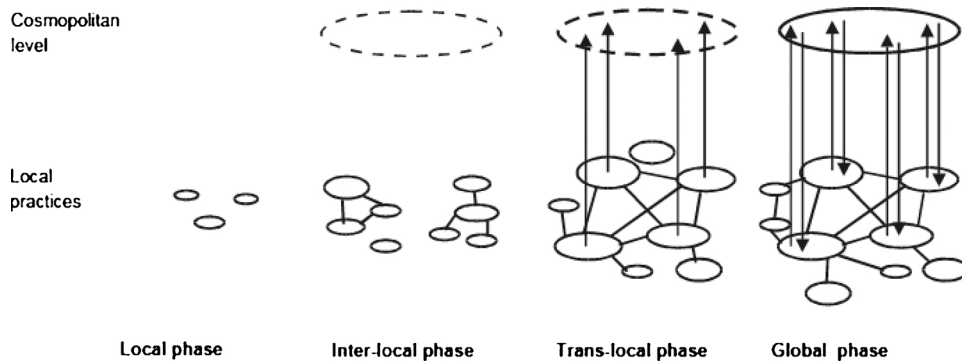

Fig. 1. Places and phases of learning according to Geels and Deuten, 2006.

In an effort to come to a sufficiently diverse as well as specific set of questions regarding the value of well-established learning approaches for a better understanding of learning in sustainability transitions, we started from the following key characteristics:

- *Actor diversity and interaction.* Regimes consist of multiple networks (Geels, 2002) with an extreme diversity of actors (public authorities, producers, suppliers, consumers, citizen groups, financiers, and so on) fulfilling specific roles and bringing in specific knowledge, interests, values, and cultural and organisational backgrounds. Whereas some actors involved in a transition process may interact on a daily basis, especially in an experiment, many actors relevant for regime change meet and exchange rarely or only indirectly. Moreover, interactions are often presented as conflictual, as tensions during experimental, socio-technological design processes in niche development on the one hand, and as the competition between niches and regimes that may destabilise regimes on the other hand. This raises the following questions: What kind of diversity is acknowledged? Under what conditions is diversity a source of learning or a barrier to it? What types of interactions are conducive to or hinder learning? What is the role of conflicts and tensions?

- *Social levels*. The levels proposed in the multi-level perspective are levels of structuration of local practices. As a consequence, niche developments can be 'overruled' by regimes, and regimes by the landscape. The higher the level, the more abstract and the harder to investigate empirically. This is perhaps the reason why learning at regime level is rarely the subject of scientific study. Although the whole idea of levels is increasingly criticised, and flat models have been proposed instead (Elzen et al., 2012), the multi-level perspective has shown great value as a heuristic, especially in the practice of transition efforts. The related questions regarding the learning traditions are: What social levels are discerned and on what basis? Can these be connected to the 'levels' of the multi-level perspective? What kind of additional insights could the learning traditions yield?
- *Timeframe*. Sustainability transitions cover change processes in many diverging timeframes. They range from (part of) a day in the form of meetings or workshops, to a few months or years in the form of, for instance, a system innovation programme, to two or three generations, which is a rule of thumb for the time needed for a full transition from beginning to end. A complicating factor for understanding the role of learning is that the transformative character of an innovation process can only be assessed in hindsight. Questions arising are thus: What are the timeframes of the learning traditions? To what extent do the traditions appear to be relevant for specific timeframes and related phases in a sustainability transition?
- *Direction of change*. By definition, sustainability transitions have a direction, in the form of an emerging pathway towards a system that provides societal functions in a more sustainable way (Elzen et al., 2011; Stirling, 2009). In addition to the normativity of the direction of change, the direction of change implies that the new pathway(s) should break through lock-ins, for which transformative processes are required. Do the learning traditions pursue a kind of normative goal (whether explicitly mentioned or implicitly suggested)? To what extent do they assume that achieving such a goal would imply a restructuration of the systems?

2.3. Analysis

To analyse the value of the learning traditions, we followed three steps for each tradition:

1 We identified its theoretical core. This is described in general terms of basic characteristics, area of application, and current progress.
2 We interpreted the core and, if needed, additional theoretical elements in the light of the four key sustainability transition characteristics. In addition, we identified the conditions under which learning is supposed or proven to take place and the kind of interventions that have proved effective, insofar as this is explicated in the literature.
3 To come to conclusions about the value of the traditions for the governance of sustainability transitions, we sought to answer a) where in a sustainability transition the kind of learning addressed could be positioned and hence be relevant, b) how it could increase the understanding of learning in sustainability transitions, and c) what suggestions it provides for triggering, supporting, and stimulating learning in transition processes.

Finally, the findings for all the traditions were compared and integrated to get an overview of the (potential) contribution of the learning traditions to the elucidation of learning in sustainability transitions and to define what gaps still remain.

3. The learning traditions

In this section, per learning tradition, we first describe their core features. Secondly, we analyse whether and how they are relevant for transitions. For an overview, see Table 1. On the basis of these steps, we arrive at conclusions about their value for understanding learning in sustainability transitions.

3.1. Collaborative learning

3.1.1. Core features

Scholars in the educational or learning sciences have concentrated on understanding learning processes in individuals and in groups. In this field, the social side of learning is present in a broad range of situations, from teacher–learner interaction to learning social entities and everything in-between (Salomon and Perkins, 1998). In a review study, the term *collaborative learning* is defined as "a situation in which two or more people learn or attempt to learn something together" (Dillenbourg, 1999, p. 1).

The concept of collaborative learning appears to be applicable to any social situation in which learning plays a role, be it educational, professional, and/or informal. Empirical work ranges from laboratory and classroom contexts to learning in the workplace and interdisciplinary learning. The concept has drawn scholarly attention because individual learning approaches rarely, if ever, take into account how social and cultural interactions shape learning (Salomon and Perkins, 1998; Akkerman et al., 2007). Furthermore, collaborative learning helps to interpret the effects of social aspects on learning. Interaction in heterogeneous groups, for instance, sometimes leads to more competence in individual learners than interaction in homogeneous groups (Sullivan Palincsar, 1998). The learning sciences include a broad variety of theoretical perspectives on learning but, to identify its value for understanding learning in transitions, we concentrate on the work related to learning in collaborative settings in which persons have mostly an equal status.

Two dominant perspectives on collaborative learning are the cognitivist and the constructivist orientation (Akkerman et al., 2007). The cognitivist orientation starts from a conceptual model of the learning individual and reasons how this model can be applied to a social situation and what this means for collaborative learning. The constructivist orientation takes the social (group)

Table 1
Comparison of the features of the learning traditions regarding transition aspects.

	Collaborative learning	Organisational learning	Social learning in natural resource management	Interactive learning in the learning economy
Diversity and interaction	Mostly equal status in the learning process Different cognitive perspectives	Shared daily routines, diverse knowledge, competences, organisational roles, interests, and values	Diverse knowledge, histories, and values, as well as diverse social roles	Departments and organisations differ in competences, organisational culture, and cognitive frameworks
Social levels	Individuals and groups of learners	Individuals (practitioners) and organisations (environment)	Individuals (stakeholders) and groups/networks of actors involved in a complex issue	Innovation systems Organisations – departments Agents
Timeframe	From meetings to projects	Continuous learning in loops of action–reflection–adaptation	From (facilitated) meetings to ongoing social learning	Continuous
Direction of change	Task-specific group performance	Effective adaptation of organisational routines to changes in context	Novel solutions and collaboration to address complex issues	Survival of firms in learning economy Economic growth
Conditions	Teacher as coach Breaking task into pieces to support task performance ICTs as both task support and communication support	Deliberation to explicate theories-in-action Systems thinking Trust Urgency and interdependence	Interdependence Trust Neutral facilitation Interactive problem analysis and development of solutions	Knowledge arrangements Government interventions Project teams, job rotation, and the like Intermediary agents Trust Shared language

level as the starting point because it cannot (easily) be reduced to its individual constituents. The constructivist orientation also regards the role of the teacher differently. Instead of being an instructor, giving his/her knowledge to the learners, the teacher is a facilitator who supports collaborative learning (Jonassen, 1991).

Different as they may be, both orientations emphasise learning as a process of sense-making or negotiation of meaning (Baker et al., 1999; Dillenbourg, 1999). In this process, people iteratively voice their own understandings, interpret others' contributions, and negotiate a new, shared understanding of a learning task (problem). As this is seen as a socially and culturally situated process, neither shared understandings in teams nor individual learning can be analysed without taking into account the social context and interaction that co-produced them.

Researchers link the necessity for collaborative learning to the complexity of learning tasks. They suggest selecting learning tasks that resemble real-world tasks (so-called authentic tasks: Hmelo-Silver, 2003) and simplifying those to connect to the learners' knowledge and experiences while keeping the structure of the problem intact. The fact that complex problem solving is usually a group effort is therefore sufficient reason for the researchers to let group work be part of a learning task (Sullivan Palincsar, 1998).

Communication in groups is seen as crucial for learning. A key topic of research is how to influence communication in order to produce specific collaborative learning results. This could be done for example with specific procedures for specific learning tasks, as exemplified by problem-based learning (Hmelo-Silver, 2003) and reciprocal teaching (Sullivan Palincsar, 1998). In the subfield of computer-supported collaborative learning (CSCL), information and communication technology (ICT) is used to support specific collaborative learning tasks, such as design (Buckingham Shum et al., 1997) and argumentation (Conklin and Begeman, 1987; Suthers, 2001). For instance, CSCL tools have been used to foster argumentation by structuring communication. Users with CSCL support have been found to be better able to elaborate on evidence for and against certain claims than users without such support (Suthers, 2001). And collaborative sense-making has been shown to benefit from making mutual misunderstandings explicit as soon as they arise (Beers et al., 2006).

The CSCL subfield also supplements the general perception of collaborative learning taking place in face-to-face communication, for instance in classroom situations. The rise of ICT has enabled distance learning, with learners communicating online either synchronously, meaning that the learners collaborate through chat-like conversations, or asynchronously, meaning that learners are free to choose when to communicate.

3.1.2. Relation with transition characteristics

Diversity and interaction: With regard to diversity and interaction, collaborative learning researchers focus mainly on individual differences, especially cognitive differences (knowing different things). These differences can be a source for learning, for instance when learners collaborate on a task. Indeed, scholars often draw a relation between complex issues and the necessity for collaborative learning; task complexity requires learners to combine multiple sources of knowledge. Conflicts can arise as a consequence of different understandings within a group process or when individual understandings do not fit a shared endeavour. Such conflicts are predominantly seen as something to be overcome in the learning process, sometimes even as conducive to the learning process: *constructive cognitive friction* refers to creating a learning task that stretches a learner sufficiently (but not too far) beyond his/her current abilities to result in learning (Vermunt and Verloop, 1999). Conflicts thus are hardly, if ever, seen as a threat to learning.

Another aspect of diversity concerns the roles of learners in a group task context, for instance when the learning task is divided

into multiple responsibilities (for example, chairperson or notetaker). However, learners are usually presumed to be of equal status, perhaps apart from the specific status of the teacher (Baker et al., 1999).

Social levels: With regard to social levels, collaborative learning research often distinguishes between the group of learners and the individual. The performance of the learners related to the learning task at hand, is assessed at either the individual or the group level.

Timeframe: With regard to duration, collaborative learning researchers focus on various timeframes, ranging from a meeting (Koschmann and LeBaron, 2003), to meeting sessions (often classroom or laboratory) of one or several hours (Beers et al., 2006), to sometimes the duration of a project (Akkerman et al., 2008).

Direction: In terms of direction of learning, collaborative learning scholars seemingly offer little in the way of a normative point of view. Rather, they sometimes include outcome indicators such as group performance/individual performance on a task. Ideally, the learning task is typical of an existing real-world task in the learners' domain. The specifics differ between types of tasks. So, the performance criteria for a design task are different from those for an argumentation task.

Conditions and governance: Learning is supported by concentrating on meaning making and structuring communication. The role of the teacher is predominantly that of a coach for learning processes. The differences among approaches are myriad, but they appear to share the idea that a collaborative task can be broken down into more manageable pieces that can be used to scaffold learning. In other words, the communication process is pre-structured ('scripted') so that the inexperienced group can learn how to complete a complex task (Dillenbourg, 1999; Sullivan Palincsar, 1998). The different ways of supporting collaborative learning are many and, as mentioned above, they are usually specific to the task at hand.

3.1.3. Relevance for understanding learning in transitions

Collaborative learning research has seldom appeared in the transitions literature, apart from some notable exceptions (Beers et al., 2016). This tradition, however, includes some notions that may well have value for sustainability transitions.

In transitions, the contexts that feature groups working together on a task can be thought of in terms of collaborative learning. Such tasks comprise the development of a niche experiment and a system innovation initiative, the development of normative future visions or transition pathways with diverse actors, and the translation of lessons learned in a pilot project to the context of a niche or regime. And of course, incumbent organisations often feature team work that entails collaborative learning processes.

The potential contribution of collaborative learning research is threefold. First, support for collaborative learning requires a task analysis and work division. It is possible to apply this principle to specific challenges in transition contexts in order to facilitate stakeholders' learning processes. This applies best to structured processes of reflexive governance, such as transition management and reflexive monitoring. Indeed, the latter approach already provides support for specific subtasks in system innovation initiatives, such as conducting a system analysis, keeping track of a dynamic learning agenda, and organising eye-opener workshops to stimulate learning between pilot projects (van Mierlo et al., 2010b).

Second, conceiving of collaborative learning as negotiation of meaning seems helpful. In transition contexts, stakeholders have very differing knowledge. In order for them to arrive at a common understanding (common ground) they need to be able to overcome differences in perspectives that influence how a person's contribution is understood (or misunderstood) by others. Misunderstandings may in particular occur when the learning actors have radically different backgrounds, which in a sustainability transition is likely to be the case when actors from a niche and the regime meet and collaborate. Some studies offer specific suggestions to support negotiation of meaning (e.g., Baker et al., 1999; Beers et al., 2006), such as explicitly verifying one's own understanding of another's contribution, delaying opinionated responses, and accepting disagreement. In other words, differences in perspective are seen as a challenge to be overcome in collaborative learning, whereas transition scholars usually see multiple perspectives mainly as a resource for dealing with societal complexity (Beers et al., 2016).

Third, learning through asynchronous communication may be relevant for learning in transition processes, for instance in the interactions between actors from niches and regimes. The time gaps and distance inherent in communication in transitions may provide room for facilitators to train actors in argumentation and communication skills as well as to urge them to reflect on their own and others' contributions before responding. Transition programmes may provide a structured context for organising such activities. If the actors involved in these programmes are willing and able to communicate, facilitators could design a collaborative process of learning as meaning making.

3.2. Organisational learning

3.2.1. Core features

The first literature on organisational learning, which is strongly rooted in management studies, appeared in the 1980s (Wang and Ahmed, 2003). For the purposes of this article, we are predominantly interested in what review studies call the normative strand in that it describes the necessary interventions to establish the conditions to operate as a learning organisation (Robinson, 2001). The most prominent scholars in this field are Argyris and Schön (1996), who distinguish multiple loops of learning, and Senge (1990), who introduced systems thinking into the field. All three influenced many other domains including policy learning, natural resource management, and innovation studies.

Organisational learning may occur when individuals within an organisation experience a problematic situation in the sense of a mismatch between expected, desired, and actual results of actions. This could be due to unexpected external developments and events or tensions with organisational standards. In response, people adapt their actions while reflecting on this mismatch (conduct 'inquiry': Argyris and Schön, 1996). Feedback or information about outcomes, characteristics, and/or consequences of actions are

considered to be the crucial mechanism in human learning and an influential element in the shaping of human practices (see also Leeuwis and van den Ban, 2004).

In organisational learning processes, individuals modify their images of the organisation and their understandings of organisational phenomena. In order to become organisational, the learning that results from organisational inquiry "must become embedded in the images of organisation held in its members' minds, and/or in the epistemological artefacts (the maps, memories and programs) embedded in the organisational environment" (Argyris and Schön, 1996, p. 16). In Argyris and Schön's (1996) terms, this means that, in order to perform tasks in a coordinated way, the 'theory-in-use' is changed; the theory-in-use consists of the frequently implicit reasons and assumptions underlying organisational behaviour.

Many authors distinguish levels of learning. When inquiry focuses on strategies for realising existing goals and does not call into question the underlying assumptions and phenomena, the associated learning is qualified as single-loop, that is, conducive to superficial and strategic change. When the learning involves changes in underlying assumptions, values, and goals, the learning is qualified as double-loop, that is, conducive to deeper change (Argyris and Schön, 1996). Such learning is accompanied by unlearning, which means that obsolete practices are abandoned.

In the case of societal/organisational complexity, effective learning seldom takes place due to 1) limited cognitive abilities, 2) defensive attitudes and reasoning (in the case of threats or embarrassment), and 3) lack of accurate feedback. The feedback that practitioners experience in their learning concerns mainly direct and close outcomes of their actions, and much less (if at all) the far-off and long-term consequences and impacts that are the hallmark of real-world complexity (Senge, 1990). Such feedbacks are available in the form of symbolic representations and interpretations rather than real-world phenomena. Hence, organisational problem solutions often evolve and are put into practice without their accuracy having been examined. These reasons limit an organisation's capacity to redesign its routines.

3.2.2. Relation with transition characteristics

Diversity and interaction: Organisational learning takes place among individuals with different backgrounds who develop and share common practices within an organisation or another setting with which they identify (a sports association for example). Diversity may consist of different knowledge, competences, and organisational roles. Although interests and values may differ between practitioners, the mere existence of the organisation is generally accepted. The additional conditions required for double-loop learning to take place are fundamentally social, see further below under "Conditions and governance".

Social levels: The key distinction in the organisational learning literature is between individual learning and organisational learning. Authors such as Argyris and Schön (1996) conceive of the relation between an individual and the organisational setting in which s/he operates as interwoven, whereas others such as Senge (1990) and Wenger (1998) view the organisation itself as a learning entity. Perceiving learning as a social event thus draws attention to the relationship between learning individuals and the organisational setting in which they operate, the notion of which shows some similarities with the concept of structuration of local practices in the multi-level perspective.

In addition to the individual and the organisational, a third social level that can be distinguished in this type of research, is the environment in which the organisation operates. The environment is usually regarded as the market, but may also be the supply chain and the political environment. It could hence be seen as part of what is supposed to constitute a socio-technological regime. The complexity of this environment may cause crises and surprises and ineffective performance, which again may prompt the organisations to adapt their actions. This is the dominant view of the relation between organisation and environment, but Robinson (2001) warns that the reverse might also be true. Organisations may well influence and transform their environments in the generic process of selecting those dimensions of the environment perceived as relevant to act upon.

Timeframe: Learning is seen as a more or less continuous process that evolves over time, across meetings and actions. The timeframe needs to be sufficiently long to include feedback from actions in a cyclical process of action(s), outcome(s), reflection, and adaptation (so, at least a couple of weeks, up to several years). Single-loop learning is a common practice every time mismatches occur; double-loop learning takes place more rarely.

Direction: In essence, the desirable direction of learning constitutes an organisation's effective adaptation, through changing organisational routines and the status quo, to changes in its context. This means that organisations apply what Argyris and Schön (1996) have named model II inquiry, meaning that views are held openly, differences are welcomed as opportunities to test the validity of assumptions, problem-solving is considered more important than maintaining the status quo, and difficulties of change, including emotional difficulties, can be discussed openly.

Conditions and governance: The main strategy suggested by Argyris and Schön (1996) to facilitate double-loop learning is essentially to make explicit what is implicit in people's practices. They suggest complementing inquiry with deliberation (reflection-on-action), in addition to the regular reflection-in-action. This could be done by identifying and discussing dilemmas with ineffective practitioners and by showing them how they have contributed to the status quo. In this way, practitioners may be stimulated to develop improved theories-in-use. Double-loop learning is likely to occur only in those situations where a person is no longer able to shut out dissonant information. In general however, people tend to ignore information that does not match their understanding of a situation, or to dismiss it as unimportant or untrue. Such defensive attitudes and reasoning could be overcome in exchanges with other practitioners with different perspectives if they contribute new and possibly counter-intuitive information. For Argyris and Schön (1996), the main inputs for such deliberation consist of detailed analyses of verbal accounts of organisational life (espoused theories). Others, however, propose eliciting the theories underlying real practices (the theories-in-use) on the basis of an ethnographic investigation of daily, routine practices and comparing these with the espoused theories (Kouévi et al., 2011). Identified incongruities between an espoused theory and a theory-in-use may then stimulate double-loop learning.

Senge (1990) identifies five basic competences (disciplines) as the prerequisites for organisations to successfully and effectively adapt to, and anticipate, a changing environment. They include an organisation's ability to help employees elicit their deeply held images and assumptions so as to open them up to the influence of others, and the organisation's capacity to have employees develop a joint understanding of a desirable future that fosters genuine commitment and engagement (rather than mere compliance). The possibility of successfully applying these disciplinary requirements hinges crucially on an organisation's ability to master the 'fifth discipline', that is, the capacity to view and appreciate the organisation as a whole rather than as an accumulation of its constituent parts (systems thinking).

Additional stimuli to reflect fundamentally on the tacit assumptions underlying common behavioural patterns include a sense of urgency, an atmosphere of trust, and commitment to reciprocity (Grin and van de Graaf, 1996; Leeuwis and van den Ban, 2004). It may also be worthwhile to develop a feeling of mutual interdependence among heterogeneous actors, meaning that they can achieve more together when dealing with a complex situation than on their own (Susskind et al., 1999). This may be a condition for, as well as an outcome of, learning (Leeuwis and van den Ban, 2004). The same holds for trust.

3.2.3. Relevance for understanding learning in transitions

Argyris and Schön's (1996) perspective has been very appealing to transition scholars as it addresses the maladaptedness of organisational behaviour, comparable to the idea of interdependent, incumbent actors resisting change, whereas they should change their routines in alignment in order to combat sustainability issues. Double-loop learning may be considered of key importance, given that sustainability transitions involve multiple, deep changes of practices that include the fundamental values that dominate current ways of life. Senge's ideas on system dynamics (1990), which build on Forrester's work (1971), have found a receptive audience among managers who engage in strategies to help realise sustainable development, e.g., among representatives of corporations that take their social responsibility seriously (Cramer and Loeber, 2004; Molnar and Mulvihill, 2003). According to Senge (2000, p. 1), "non-systemic ways of thinking and acting" are at the core of unsustainable practices and can be tackled by "building [learning] enterprises that operate in greater harmony with larger social and ecological systems."

Organisational learning also sheds light on the conditions under which undesirable organisational routines may or may not change and the types of interventions that may trigger double-loop learning. This knowledge may apply to initiatives and niche experiments in which actors cooperate closely, as well as for transition-relevant contexts, such as grassroots innovations, social movements, and the constituencies in the incumbent regime or any other context in which individuals share practices with others.

In the pursuit of sustainability transitions, it is useful to conceptualise learning as a string of social events and actions, resulting from reflection in interaction on feedback. After all, the changes implied require joint action by large numbers of actors. However, organisational learning applies only to actors interacting on a daily basis in organisations or temporary projects or initiatives; this may conceal more overt conflicts and detrimental practices playing a role in transitions. Yet again, the organisational learning literature elucidates why a multi-actor context, as in transitions, can never by fully known. The results of the actions of many non-participating others appear to the learning individual or organisations mainly in the guise of a deeply uncertain, amorphous environment, for instance when they become relevant and concrete as crises and surprises. The outcomes of others' actions will furthermore be experienced via institutional arrangements that either constrain or increase the room for manoeuvre and be known via mediated, limited information (Loeber et al., 2007).

Organisational learning hence is insightful regarding how organisations may learn to change their daily practices in interaction. In order to understand learning in sustainability transitions better, it would be important to, in addition, discern the mediated interaction between organisations at a distance from one another as a form of learning, feedback, and knowledge generation.

3.3. Social learning in natural resource management

3.3.1. Core features

The term social learning is key for researchers studying learning related to natural resource management (see e.g., the review of Rodela, 2011). It emphasises the importance of integrating knowledge from multiple perspectives. Social learning occurs when heterogeneous actors share their knowledge in an interactive process to produce new knowledge and trust, which, in turn, serve as the basis for joint action (Pahl-Wostl, 2006). Social learning theory treats actor diversity (in terms of knowledge, values, interests, goals) as an important resource for dealing with complex issues (Ison and Watson, 2007; Wals, 2007).

The main context of interest for social learning scholars consists of natural resource issues situated in socio-ecological systems, that is, complex real-world systems that combine social and ecological systems. These systems are described in terms of general behaviours and basic characteristics resembling complex dynamic systems (e.g., feedbacks and delays, nonlinear behaviour, uncertainties). In that sense, the field of social learning is clearly, although somewhat implicitly, rooted in system dynamics (Forrester, 1971; Sterman, 1994).

The literature typically views social learning in terms of its inputs and outcomes, with stakeholder diversity (knowledge, interests, values, resources) as input and novel solutions to complex societal problems as outcomes (Beers et al., 2016). Most authors distinguish cognitive from relational outcomes of social learning (Pahl-Wostl, 2006). The cognitive outcomes concern, for instance, new insights and innovative solutions for sustainability issues. These can be seen as the knowledge content of social learning. The relational outcomes refer to, among other things, the emergence of trust among the stakeholders and the new social networks that are formed when stakeholders become aware of their mutual interdependencies.

Recently, Reed et al. (2010) and several others (e.g., Cundill, 2010; Koutsouris and Papadopoulos, 2003; Rodela, 2011; Scholz et al., 2014) have criticised earlier social learning studies. In order to progress the conceptual and methodological grounds of social

learning, they propose, among other things, distinguishing more clearly between process, outcomes, and impacts of social learning. This is expected to provide a fuller understanding of how to support social learning and what it might bring about. Another suggestion is to pay more attention to naturally occurring processes of social learning rather than the facilitated learning processes that have been at the core of many empirical studies.

3.3.2. Relation with transition characteristics

Diversity and interaction: Stakeholder diversity, in terms of knowledge, history, values, and interests, is predominantly seen as a benefit for dealing with natural resource issues, as the complexity of these issues makes it impossible to tackle them from only one perspective. Rather, actors are bound together in their relation to the issue and can deal with it by bringing their diverse perspectives and resources together as a basis for joint action.

Social levels: Social learning applies to a group of – potentially dissimilar – stakeholders. Reed et al. (2010) assert that social learning includes both individual learning and learning across wider networks and systems. The social learning literature often reports proceedings of facilitated workshops, suggesting that the (organised) group level is an important unit of analysis. Reed et al. (2010) emphasise that social learning can (should) also be analysed in learning individuals and in wider networks that go beyond the level of multi-stakeholder groups. While mutual dependency, for instance for effective water shed management, is seen as key to learning, structuration of local practices by rules and technical artefacts is not recognised in this learning approach.

Timeframe: Conceptually, social learning concerns various timescales. Empirical studies, however, are often limited to single events rather than longer time spans (Reed et al., 2010). Those studies investigate learning during (workshop) meetings, sometimes including actions in between meetings. Other studies take a more longitudinal approach, with few or no facilitated events, and include results and outcomes of social learning occurring over longer timeframes.

Direction: The process of social learning is thought to involve a content aspect and a relational aspect. Successful social learning yields knowledge and relational outcomes that provide a basis for joint action regarding the natural resource issue, like in an integrated water management programme.

Conditions and governance: The most important precondition for social learning to take place appears to be mutual dependence among different actors in a real-world context (Schusler et al., 2003). In such a situation, it is possible to produce innovative solutions through sharing knowledge, building relationships, and working together. To be successful, social learning requires open communication in which participants feel free to share their individual perspectives, in which they feel respected by others, and in which they can freely disagree, to the extent of being able to have a constructive conflict (Schusler et al., 2003; van Bommel et al., 2009).

Both the content and the relational aspect of social learning as distinguished in the literature provide additional conditions and governance leverage for facilitation. Regarding the content, researchers can provide facilitation to arrive at a shared problem analysis, for instance with participatory system analyses. In so doing, participants may achieve a better understanding of the problem and how they and others are related to it and to one another. Pahl-Wostl and Hare (2004), for example, report on a social learning process that was supported using techniques for knowledge elicitation from soft systems methodology (Checkland, 1981) and group model building using system dynamics (Vennix, 1996), complemented with model simulations and role playing (Pahl-Wostl and Hare, 2004). In a sense, such a group process may help participants to recognise that their own interests are as legitimate as those of others (Schusler et al., 2003). Regarding relations, trust is often mentioned as the most important condition for social learning as well as a potential outcome. Ensor and Harvey (2015) emphasise the importance of facilitating social learning by eliciting stakeholders' perspectives and issue framings. Facilitation could contribute to trust if facilitators take a relatively neutral role. Furthermore, social learning can benefit from procedures and institutions that address differences in power, knowledge, and resources.

3.3.3. Relevance for understanding learning in transitions

The term social learning itself has a long history of being theoretically linked to sustainability issues. Nonetheless, theories of social learning have rarely been applied by transition scholars, despite the fact that the term social learning is mentioned quite often in transition studies. Moreover, social learning shares with transition science an emphasis on actor diversity (knowledge, values, interests, goals) and also addresses, to some extent, the fact that this diversity is part and parcel of both learning process and outcomes. Another shared feature is the focus on action-oriented (learning) outcomes – learning outcomes that form the basis for joint action and the mutual trust among stakeholders that joint actions require (Pahl-Wostl and Hare, 2004; Pahl-Wostl, 2006). Furthermore, the natural resource management issues that have attracted so much attention from social learning scholars are, in many respects, similar to transitions in terms of the underlying systemic complexity (see e.g., Rotmans and Loorbach, 2009). Indeed, in both domains, actor diversity is seen as beneficial, especially because it is seen as a prerequisite for dealing with complexity. Social learning is about learning in wide, informal networks of actors that meet occasionally because they are addressing an issue of mutual interest. These similarities might well stem from the fact that both domains are partly rooted in system dynamics.

Most of the social learning literature concentrates on multi-actor collaborations, which, in a sustainability transition, can be recognised in niche experiments, in facilitated transition arenas, and in specific places in the socio-technological regime, for instance in collaborations between large companies and environmental NGOs (van Huijstee and Glasbergen, 2010). The main characteristics of social learning hence appear to be directly applicable to many forms of learning in a sustainability transition. It appears helpful to differentiate knowledge increased in the exchange between stakeholders from relational networks emerging from the learning process. This has already been done in, among others, strategic niche management studies (Schot and Geels, 2008).

The emphasis in the social learning literature on diversity, open communication, room for change, and facilitation seems reflected in writings about structured processes of reflexive governance, such as transition management and reflexive monitoring. For example, the transition arena, as a central phenomenon of transition management (Loorbach and Rotmans, 2006; Rotmans and Loorbach,

2009), uses the diversity among group members as a resource for creativity in terms of forecasting and backcasting (future visioning) and collaborative problem analysis. Additionally, transition arena members are expected to learn to overcome their differences and recognise the potential of building on others' ideas and resources, much like how a sense of mutual interdependence can foster social learning. However, transition contexts differ in the sense that, although some consensus appears to be necessary for co-ordinated action, scholars also emphasise the importance of being able to disagree about both current-day problems and preferred future visions. So, the learning process in a transition arena does not aim for a joint basis for action. Indeed, the term *arena*, as used in transition management, invokes the image of a clash of beliefs and convictions to reach future visions. For learning, this means that important differences of opinion are not addressed as an obstacle to be overcome but as a way to open up the innovation process and develop multiple options and pathways towards more sustainable production–consumption sectors. This stands in contrast to the image elicited in social learning writings (Muro and Jeffrey, 2008).

In sum, the social learning literature has many similarities with the transition science literature. One might even argue that they are conceptually close fields, being grounded on similar scientific roots about systemic complexity. Perhaps it should therefore not come as a surprise that techniques to foster social learning (e.g., problem analysis, group building) are similar in both nature and aims to techniques used in transition management. This explains why social learning does not add so many additional insights about learning in sustainability transitions, beyond better explicating the concept of learning itself.

3.4. Interactive learning in the learning economy

3.4.1. Core features

In innovation science, several scholars deduce that knowledge and learning are at the heart of modern economies (Rosenberg, 1982; Arrow, 1962). Among the different strands in this field, Lundvall is recognised as the most influential scholar (see the reviews of Hudson, 1999 and MacKinnon et al., 2002). In his seminal works, Lundvall (1992, 2017) speaks of the 'learning economy', that is, an economy in which the pace of the creation and destruction of knowledge has become very fast. As the result of widespread ICT, flexible specialisation, and innovation, the learning economy has become established firmly; this is when firms start to learn how to learn.

Key to a learning economy is interactive learning (or 'learning-by-interacting'), which is essentially a process of increasing knowledge by creatively combining codified and tacit knowledge (Nelson and Winter, 1985). The latter is abundantly available according to this perspective. Different kinds of knowledge are distinguished: know-why (general principles and laws) and know-what (facts), which are codify-able, and know-how (skills) and know-who (who can do what), which are context specific. In a learning economy, interactions take place not only in science and technology systems, which are specifically organised to increase knowledge, but also in more anonymous and mundane ways, that are specific to the characteristics of the local context, in and between companies and their departments (Nelson and Winter, 1985; Neij et al., 2017). Effective interactive learning is accompanied by the opposite knowledge process: 'creative forgetting' (see also 'creative destruction': Schumpeter, 1942) – the reduction of knowledge. Old, ineffective habits have to be left behind in a process of unlearning.

The core notion in this type of work is that of systems of innovation, which consist of networks of actors who interact in the production, diffusion, and use of new and economically useful knowledge in an institutional context that affects their interaction. Components of the innovation system, that is, agents, institutions, and technological aspects, reinforce one another in promoting processes of learning, or they block such processes because of system imperfections. It is argued that the way in which suppliers and consumers are related, and the institutional set-up within firms, between firms, and in policymaking, greatly define the speed of learning and innovation. This is in sharp contrast to views in which institutional change is predominantly conceived of as merely hindering innovation or lagging behind other changes, such as new technological knowledge.

3.4.2. Relation with transition characteristics

Diversity and interaction: In the co-evolutionary economic tradition, firms are assumed to differ in their capabilities, organisation, culture, and cognitive frameworks. Consequently, there are major differences regarding their economic competence, that is, their capacity to create knowledge and tap into their (tacit) knowledge bases and make them productive (Morgan, 2004). Early work concentrated on interactive learning between producers and users in an innovation system. Recently, learning at the workplace has become more prominent, that is, learning within a productive organisation and between producers (Lundvall, 2017). Interactive learning hence takes place at a variety of interfaces inside and outside firms.

Conflicts do not play a dominant role in the core body of this thinking, apart from the competition between firms in the market, between different economies, and between user groups. As the producers are interested in disclosing information about new technologies, products, and process innovations to their potential customers, competition in the market tends to stimulate innovation (Mytelka, 2000).

Social levels: In innovation system analyses, learning indicators are usually applied at the system level. Whereas national innovation systems were the main focus of the earlier work, recent books and studies have turned to discussing the implications of globalisation and digitalisation for economic development. Simultaneously, there is a revival of interest in the meaning for learning in regional innovation systems in response to claims that geographical proximity has become less important under the influence of ICTs (Morgan, 2004). Other types of innovation systems are sectoral and technological. Sectoral innovation systems are "a set of products and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products" (Malerba, 2002, p. 247). Technological innovation systems are generally related to a specific technological novelty. The rules guiding the practices in all these innovation systems, are regarded as a necessity for innovation rather than barriers for desirable change.

Timeframe: In the current post-Fordist era, learning and innovation take place continuously in well-functioning systems and in learning organisations (in contrast to static organisations: Lundvall, 2017).

Direction: Ideally, the innovation system is conducive to continuous learning by competent companies that contribute to economic growth. Sharing knowledge and synthesising codified and tacit knowledge are essential for the continuous, incremental innovation that is needed for the survival of firms: "For instance, the absolute scarcity of certain crucial natural resources can be overcome when knowledge abundance is exploited through global sharing of technological and organisational knowledge" (Lundvall, 2017, p. 15).

Conditions and governance: Incentives for interactive learning and thus continuous innovation at the diverse interfaces are seen to consist of: 1) effective arrangements, 2) process conditions, and 3) the emergence of necessary functions of innovation systems.

Formal arrangements for generating knowledge systematically – for example in universities, research institutes, and R&D departments – involve intense and complex forms of interaction. Government interventions are suggested to be oriented primarily towards shaping the overall system to promote self-organised learning that reduces the need for interventions in the economy. Arrangements for organisational learning include horizontal flows of knowledge, vertical integration of a value chain, problem-solving project teams, job and task rotation and broad job descriptions, compensation measures for victims of change, and intermediary agents creating links between knowledge producers and users.

Relevant process conditions concern, among others, reciprocity and the expectation of meeting again, because know-who and know-how cannot be easily translated into codes that other actors understand (Morgan, 2004). Trust can accelerate interactive learning because it provides all actors access to thicker and richer information. A mutually understandable language developed in dialogues or other forms of face-to-face communication makes it possible to build trust, especially if the actors involved in the exchange of knowledge have diverse cultural backgrounds and thus interpret similar information differently (von Krogh et al., 2000). Attention to complex communication is especially important in the broader process of interactive learning involving several formally independent users and producers, as good interaction within a company often comes at the cost of little learning with actors in the context of the company.

Finally, the fulfilling of specific functions in newly developing technological innovation systems that emerge around promising sustainable technology is addressed with functionalist approaches (Hekkert et al., 2007). Learning is related to two of the seven systemic functions that should be fulfilled: knowledge development and knowledge diffusion in networks.

3.4.3. Relevance for understanding learning in transitions

In transition studies, so far, innovation system analyses have been used primarily to study learning in the form of knowledge development and diffusion in technological innovation systems, comparable to niches, as well as to study learning regarding system failures (see for instance Negro et al., 2008; van Mierlo et al., 2010a). Transition scholars have also been inspired by this learning field to develop ideas about the geographical dimensions of transitions (Coenen et al., 2012). Innovation system thinking is, however, also criticised for being limited for understanding the *re*-structuring that should take place in the incumbent regime (Loeber et al., 2007). For transitions to take place, the current pathways of change need to be redirected in a more sustainable direction and lock-ins within the current systems firmly addressed. The latter has recently been fully acknowledged by Lundvall himself (2017, p. 389): environmental sustainability "… requires radical changes not only in technologies but also in values, institutions, policies and consumption patterns. … Vested interests, nationalism, financialisation, pro-market dogma and political short-termism constitute barriers for change."

The co-evolutionary perspective on innovation and learning draws attention to the institutional setting of learning. Transition studies locate learning predominantly in niches that are shielded from market pressure, in which learning may trigger novel, emerging institutional contexts, or in technological innovation systems. In contrast, learning in learning economies is seen as the result of a conducive institutional environment. This raises the question of the extent to which current consumption–production systems in specific economic sectors (regimes) can be regarded and analysed as learning economies.

From such a perspective, learning *in* incumbent systems would become a key issue to investigate. Change among incumbents would be considered to be taking place in and through (un)learning rather than being 'merely' the result of landscape pressure, interaction with niches, and the resulting system-internal tensions. A co-evolutionary analysis would focus attention on the abundant, ever present, and important tacit knowledge and the continuous process of codifying knowledge. With the latter, innovation scholars address not only the (im-)possibility of codifying some kinds of knowledge of which people themselves are not aware, but also the – often high – transaction costs for doing it (Morgan, 2004). Moreover, the high variation in novelties resulting from interactive learning in incumbent systems may well enlarge the potential for sector transformations (compare the notion of diversity promoted in the pathways approach of the STEPS centre: Stirling, 2009). Following up on this thinking would mean loosening up the harsh dichotomies of incumbent versus niche actors, and of radical and incremental innovation and learning in niches versus conflicts in and with regimes, as suggested in transition studies that draw on empirical work (see e.g., Elzen et al., 2012).

4. Value of the learning traditions

The findings confirm that current fields of learning provide valuable insights, albeit varying in the extent to which they are specific to, and informative for, transitions, and in how they are so (see Table 1). Highlights of the added value of the investigated research programmes are:

- Collaborative learning is a relevant entry point as it regards learning as a process of sense-making rather than knowledge transfer,

similar to transition scholars' understanding of learning. Our analysis suggests that transition-specific challenges (such as translating learning outcomes from a niche to regimes) may be regarded and addressed as complex tasks in the light of the collaborative learning tradition. They could be handled with an approach of analysing and dividing tasks and responsibilities with the support of a coach. A specific challenge in sustainability transitions is to deal with conflicts, for which collaborative learning may provide some assistance as well. Furthermore, collaborative learning highlights the possibilities for synchronous and asynchronous learning between distant actors. This could be expected to take place during the abundant indirect interactions of actors involved in 'transitions in the making', which outweigh direct interactions in transition experiments.

- Organisational learning has rightly been embraced in transition studies for its distinction between single- and double-loop learning, or more simply: superficial and deep learning. Deep learning is assumed to be crucial to escape path dependency and lock-in. This learning tradition provides ample entry points to facilitate deep learning in the organisation of incumbent actors by instigating reflection on experiences in a process of deliberation and face-to-face communication. It could also serve as a basis to monitor such learning processes. It remains to be investigated to what extent these insights also apply directly to transition arenas and niche experiments in which actors do not share an organisational culture. The key value of this field for transition studies, however, is that it provides a wider perspective on learning in sustainability transitions. It urges a focus not only on those rare occasions in which deep learning and radical change is hoped or expected to take place, but also on those in which superficial learning takes place and actors are subject to psychological mechanisms to resist change.

- Social learning in natural resource management has many similarities with the current dominant perspective on learning in transition studies: the multi-stakeholder character of learning, the focus on transformative change, and the diverse timescales. Its potential added value is primarily conceptual, as it stems from a long-standing tradition in which learning concepts are discussed and empirically grounded. The distinctions between the content and the relational aspect of learning, and more recently between learning process and learning outcomes, seem applicable in the transition context, in instances where multi-stakeholder groups gather to address an issue of mutual interest and negotiate and take co-ordinated action.

- In contrast to the other investigated learning fields, interactive learning starts its analyses at system level. Thus, it provides suggestions for investigating learning both within regimes and at a more abstract level, even though it does not distinguish between incremental and transformative change. The theoretical framework is an interesting entry point and rich source for studying so far uncovered forms of learning in transitions. It would shift the focus to learning among incumbents and give attention to the abundant tacit knowledge and the process of codifying this knowledge in relation to the transaction costs for doing this. In line with this thinking, socio-technological regimes would be investigated as a sectoral innovation system. Moreover, its ideas about learning as the result of a conducive institutional context seem relevant for transitions in addition to well-known conditions like trust. A final potential contribution is its proposition to regard learning as a process that coincides with forgetting and unlearning, which is most relevant in the transition process of actors changing their everyday practices.

Other learning traditions may well provide further valuable insights. Interesting learning traditions that could be investigated on their merit for transitions include: policy learning grounded in policy sciences (Bennett and Howlett, 1992; Grin and Loeber, 2006); learning in communities of practices (Brown et al., 1989; Lave and Wenger, 1991) grounded in management studies; and cultural historical activity theory (CHAT: Engeström, 1999; Roth and Lee, 2007) and transformative learning (Mezirow, 1997), both grounded in educational sciences.

5. Discussion

In the following, with the aim of inspiring further research on the topic, we make a first attempt to describe what an elaborated perspective on learning in transitions could look like. We distinguish two main modes of learning in transitions: discursive interaction and reflective action.

Learning as *discursive interaction* takes place in the form of exchanging knowledge, information, and meanings, both within and between meetings, both face-to-face and asynchronously (Beers et al., 2016). Learning in this sense can be seen as predominantly cognitive, while being informed by diverse knowledge, values, and interests, in a process of meaning making. At times, this may result in convergent problem orientations and common ground. At other times, discussion partners may gain a better view of the grounds upon which their opinions differ. In both cases, the result is a shared cognitive basis.

Beyond discursive interaction, learning takes place in the form of *reflective action*. This iterative process of action and reflection involves activities of planning, action, and evaluation, which may give rise to the emergence of changing practices. In that sense, it necessarily includes discursive interaction. The learning mode of reflective action concerns a search for what works and what does not work, given the complex problems that inhibit sufficient problem analysis. In that sense, it applies just as well to actors in niches as to incumbent actors or transition arenas.

Reflective action includes the material commitment to action – actually doing stuff – as well as the experiences that may stem from that action, not only in the sense of new knowledge, but also in the sense of emerging trust. Thus, learning as reflective action takes place over longer timeframes and includes notions from organisational learning and social learning about the emergence of trust and new knowledge through action and reflection. In doing so, communicative exchange and reflective action co-evolve in transitions, yielding both cognitive and relational capital. The build-up of such capital is normative in the sense that it has a direction – towards radical systemic change. Furthermore, it strengthens the basis for further actions. In that sense, a successful learning process has a self-reinforcing capacity.

Any learning in transitions occurs in an existing, changing material and institutional context. This context may influence the

learning process in the form of setting the agenda and constraining the room for change, but it may also enable learning, for instance when governments finance transition-oriented innovation programmes. In the longer term, learning groups may reflexively start to influence their environment so as to make it more conducive to transitions (Beers and van Mierlo, 2017). Together, the environment and the learning process produce the evolutionary selection processes that characterise transitions in the making (Raven et al., 2008).

Learning in transitions has thus far been studied primarily as a process starting in pilot projects or niches developing systemic properties, if successful. A learning process conducive to a transition, however, includes developing new knowledge, routines, and relations as much as doing away with the old (unlearning); includes intensive interaction supposed to stimulate deep learning as well as distant, extensive, and indirect interactions; and takes place in early phases as well as later phases of a transition. It encompasses a process of actors seeking change towards sustainability as well as countless others who do not share such intentions. Moreover, a transition process can be expected to be rife with learning about how to resist change, more specifically to hinder transition efforts and block a transition pathway.

A better understanding of learning in sustainability transitions ultimately needs to be developed in and through interdisciplinary empirical studies in which researchers from both transition studies and the learning traditions collaborate, while openly discussing and overcoming paradigmatic differences. Further theoretical developments and creative crossovers are needed to address the following challenges:

- The gap between the detailed understanding of learning by individuals and the abstract understanding of learning implied in the generic learning capacities of an organisation and effective institutional arrangements in innovation systems. How is individual learning conducive, or a barrier, to organisational and system learning? Is it necessary to study and monitor individual learning or would a focus on organisational and system learning suffice?
- The ambiguity regarding the differences between learning processes and outcomes. Empirical studies tend to focus on either the process (especially in education studies) or the learning outcomes (most prominently in innovation studies), presuming a positive relationship. When, where, and how are learning processes and learning outcomes indeed positively related, and conducive, to a transition process?
- The uncertainty about the relative importance of the numerous conditions suggested by the learning traditions. How important are, for example, diversity and trust and the role of facilitators, teachers, and the government in the various places and phases of sustainability transitions?
- The unknown relation between superficial and deep learning. It is common practice in almost all empirical learning studies to ignore either one or the other. Rather, their relationship should be critically studied with clearly operationalised concepts of the two learning types. When and how does learning contribute to transformative change and how does it build on, or conflict with, everyday learning? What is the role of the abundance of tacit knowledge available in both superficial and deep learning?

6. Conclusion

Summing up the heritage of the four learning traditions investigated here in terms of their value for a transition perspective, we determined that three of them apply to settings in which actors collaborate on a task; collaborative, organisational and social learning. They hence can be (and have been made already) relevant for learning in pilot projects and, if close interaction takes place, also between pilot projects, that is, in a niche. In addition, all four traditions (including interactive learning) are promising for shedding more light on learning in teams, departments, and organisations operating within regimes, while being under pressure from landscape developments. How do incumbent actors deal with emerging tensions? When and how are they able to restructure their daily routines rather than just change their espoused theories ('greenwashing')? All traditions might aid in increasing such knowledge on learning by incumbent actors – a neglected area in transition studies.

Overall, the learning approaches analysed here include a diversity of contexts in which learning processes relevant for transitions are taking place. Hence, we conclude that the investigated learning traditions provide ample opportunity for increasing the understanding of learning in sustainability transitions and how to foster it. Specific research questions and transition governance challenges could be addressed by creatively combining salient elements of the wealth of these traditions.

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