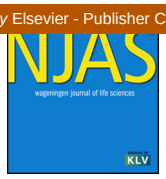
NJAS - Wageningen Journal of Life Sciences 69 (2014) 23–38

NJAS - Wageningen Journal of Life Sciences

journal homepage: www.elsevier.com/locate/njas



Multi-Loop Social Learning for Sustainable Land and Water Governance: Towards a Research Agenda on the Potential of Virtual Learning Platforms

Wietske Medema[a,*], Arjen Wals[b], Jan Adamowski[a]

[a] Department of Bioresource Engineering, McGill University, Ste Anne de Bellevue, Quebec, Canada
[b] Department of Social Sciences, Education and Competence Studies, Wageningen University, Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 19 August 2013
Accepted 21 March 2014
Available online 5 May 2014

Keywords:
multi-loop social learning
sustainable land and water governance
virtual learning platforms
multi-stakeholder collaboration
reflexivity
change process
horizontal and vertical integration
innovative learning partnerships

ABSTRACT

Managing social-ecological systems and human well being in a sustainable way requires knowledge of these systems in their full complexity. Multi-loop social learning is recognized as a crucial element to sustainable decision-making for land and water resources management involving a process of managing change where the central methodological concern is with effectively engaging the necessary participation of system members in contributing to the collective knowledge of the system. Ensuring the inclusion of the community of concern may help to ensure robust knowledge, the necessary plurality of views, responsibility sharing and trust enhancement. This will also provide more dynamic lines of input to problem solving: local and changing forms of knowledge, emerging concerns and constraints all feed into an ongoing decision-making process. This conceptual paper is focused specifically on identifying the key drivers and conditions that facilitate multi-loop social learning and the untapped potential of virtual learning platforms in this context. The hyper-connectivity that characterizes digitally mediated networks opens up significant possibilities for information exchange, knowledge creation, feedback, debate, learning and innovation, social networking, and so on. This paper provides a thorough literature review of the conditions and affordances that are conducive to multi-loop social learning in the context of sustainable land and water governance. The insights from this review confirm the potential of a 'learning ecology' or virtual learning platform for knowledge co-production, trust building, sense making, critical self-reflection, vertical and horizontal collaboration, and conflict resolution, while serving as a facilitating platform between different levels of governance, and across resource and knowledge systems. To conclude this paper, a developmental research agenda is proposed to refine and improve understanding of multi-loop social learning processes and their effective facilitation through virtual learning platforms.

Contents

* Corresponding author. Department of Bioresource Engineering, McGill University, Ste Anne de Bellevue, Quebec, H9X 3V9, Canada. Tel.: +514 398 7836.
E-mail address: wietske.medema@mcgill.ca (W. Medema).

http://dx.doi.org/10.1016/j.njas.2014.03.003
1573-5214/

1. Introduction

The overall purpose of this paper is to provide a thorough literature review of the conditions and affordances that are important to facilitate multi-loop social learning. Subsequently, a research agenda is proposed that focuses on the so far relatively untapped potential and opportunities of virtual learning platforms to facilitate multi-loop social learning processes that address the complex, multi-dimensional challenges to sustainable land and water resources management. Multi-loop social learning is increasingly viewed as a crucial element to sustainable decision-making in the field of land and water resources management, involving ongoing reflection, not only on objectives, actions and outcomes but also on the interactive process and individual and group learning that takes place during this process [1–7]. The sustainable governance of land and water resources has become one of the major challenges for environmental policy in the 21st century due to factors such as population growth, climate variability and uncertainty, regulatory requirements, and transboundary considerations [3,8–11]. Addressing the challenges posed for sustainable resource governance is hampered by serious knowledge gaps and the lack of a sound conceptual base to understand learning and change in multi-level governance regimes [3,12–14]. In this light, more emphasis has to be given to network governance and processes of social learning [5,15,16].

Despite decades of research into sustainable governance systems, there remains a gap between theory and practice [17]. Multi-stakeholder collaboration and multi-loop social learning processes have been recognized as key elements to understanding and developing collective commitment and capacity to tackle increasingly complex problems with innovative and creative solutions [18–20]. Learning processes in particular have increasingly become the focus of much social-ecological systems literature with emphasis on social learning and self-organized learning processes through collaboration, joint decision-making and multi-stakeholder arrangements (e.g. [1,2,4,5,21,22]. The ability of regional and local collaborative groups and networks to: (a) integrate different sources of knowledge; (b) to undertake iterative and transformative planning and management change in response to new learning and information; and (c) to ensure that there is an impact from such collaborative efforts, are key potential areas for effective facilitation of sustainable land and water governance [18,19,23].

In this light, it is essential to recognize multi-loop social learning as a process of managing change, where the central methodological concern is with effectively engaging the necessary participation of system members in contributing to the collective knowledge of the system with the aim to generate more sustainable policy choices for land and water resources management [1,15,24]. Although social learning is increasingly viewed as crucial for the transition to more sustainable land and water resources governance, not much effort has yet been put into defining how to achieve this in a practical sense [25]. And although there seems to be a shared understanding of some of the key aspects of social learning, its outcomes and contributions to sustainable land and water resources management, the academic literature neglects to reflect an unambiguous specification of multi-loop social learning as a process, as well as to provide strong empirical evidence on the role of social learning in decision making regarding land and water resources [e.g. [1,26,27].

In other words, not much is known about how to effectively facilitate social learning processes, about whom to involve and to what extent [2,15]. In addition, the required horizontal links (between local actors) and vertical links (navigating the larger environment) between relevant organizations, institutions and knowledge systems have received relatively little attention [21,28–31]. It is crucial, therefore, to develop a much greater understanding of whom to involve in social learning processes and how to effectively facilitate multi-loop social learning processes while taking into account the vertical and horizontal linkages among learners and learning communities. Additionally, it is important to develop greater specificity when it comes to learning expectations and processes in policy making and in natural resource management practices if learning processes are to be linked to learning outcomes [5,26]. Clearly articulated learning goals are fundamental to effective monitoring and evaluation of learning outcomes [32,33].

When it comes to promoting and intensifying the application of social learning, participatory learning platforms need to be established where individuals can meet, interact, learn collaboratively and take collective decisions [27]. Although there is evidence that participatory processes may stimulate and facilitate social learn [34] it cannot be automatically assumed that collaboration implies that social learning takes place [35]. In order for social learning to occur when stakeholders are brought together to deal with their differences and collaborate, it is crucial to nurture opportunities for learning [26]. Reed *et al.* (2010) state that there have been numerous examples of supposed social learning projects that simply facilitated stakeholder participation and collaboration, but that have not shown clear empirical evidence of multi-loop social learning.

Reed *et* al. (2010) also suggest that for multi-loop social learning to occur, a change in understanding and behavior must take place in the individuals involved. Subsequently, for a phenomenon to be described as social learning, it must demonstrate 'a change of understanding that takes place amongst both individuals and small groups to become situated within and diffused to wider social units or communities of practice'. Ultimately, however, it is critical to note that it is not just the change in understanding or the scale at which it takes place that denotes social learning, but also the mode of social interaction through which learning occurs [1]: (i) information transmission (i.e., simple learning of new facts through social interaction); and (ii) deliberation (referring to dialogue and a genuine exchange of arguments). These social interactions may take place directly (e.g., conversation) or indirectly (e.g., social media, telephone, or Web 2.0 applications).

Most research on collaborative approaches to social learning for sustainable land and water management [36,37] focuses on face-to-face interactions. A vexing issue remains who participates and how do different actors and stakeholders acquire the right or ability to participate in learning processes. It is crucial to give a much greater amount of attention to the potential of innovative learning environments that enable different segments of heterogeneous communities an opportunity to transform traditionally disadvantageous power relations and engage in truly collaborative social learning [2] thus democratizing the decision-making process [38].

Finally, the prospects and possibilities of supporting social learning-oriented sustainable land and water governance through ICTs seem more obvious as the digital age offers increasingly sophisticated and user-friendly virtual interfaces. However, here too it can be argued that these claims are rather intuitive without solid grounding in theory and practice [39,40]. A review of these prospects and possibilities can help stakeholders move beyond the intuitive. It should also be noted, that these virtual learning environments are not meant to completely replace existing systems; these interactive learning platforms that enable the virtual connection of a diverse and local, regional and global audience will need to be effectively linked or interfaced with direct and face-to-face interactions since both forums offer a different quality.

In the context of this general analysis the following topics have been reviewed in order to gain a more in-depth understanding of what conditions and factors are supportive to effectively and innovatively facilitate double-, and triple-loop social learning processes while also taking into account vertical and horizontal linkages among learners and learning communities:

- *Social learning as a process of managing change*: in particular reviewing organizational change management literature that help to understand the different levels and scope that multi-loop social learning processes consist of;
- *Conditions for multi-loop social learning:* reviewing and analyzing lessons learned from recent empirical research on multi-loop social learning in the context of land and water resources management, and providing a preliminary framework that provides insight into what is required to successfully facilitate double- and triple-loop learning;
- *The premises of virtual learning platforms:* analyzing existing academic literature on virtual learning platforms (including e.g. multiplayer social games) while linking associated claims and benefits of such platforms to the required conditions for facilitation of multi-loop social learning for sustainable land and water resources management.

Based on the review we end this paper by constructing a developmental research agenda that can help refine and improve understanding of multi-loop social learning processes and their effective facilitation through virtual learning platforms.

2. Social Learning as a Process of Managing Change

Social learning for sustainable land and water governance is in principle all about 'managing processes of social change' [41], in which people learn from one another in ways that may benefit wider social-ecological systems [42–47]. Alexander *et al.* (2009: 186) define learning as "a multidimensional process that results in a relatively enduring change in a person or persons, and consequently of how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially" [48]. Learning, in other words, can be viewed as change, first in perceptions and then in behaviors [49]. Social-ecological systems are complex, which means that change processes are dynamic and often unpredictable. Effective change processes, therefore, are required to build shared understanding and collective learning processes that enable multiple stakeholders to respond and adapt to the uncertainty of how change unfolds in practice. To achieve more sustainable land and water management practices a (transformational) change is required in current water management regimes [36]: from changes in strategies and actions, in individual and collective beliefs and behaviors, and in management processes, to the establishment of entirely new organizations and structures within the prevailing socio-ecological systems.

Whilst societies and systems have always had to confront the repercussions of change, over the recent decades the magnitude of change has increased significantly. Fundamental issues that have contributed to this dramatic increase in magnitude of change are: faster communication and knowledge acquisition, growing worldwide populations, increasing inter-dependence and competition, limited resources, constant transitions of power, and, ecological distress and runaway climate change [50,51]. Interactions between these factors have a significant impact on the volume, momentum, and complexity of change, and demand a radical shift in the way people think, how they feel, what they believe and how they behave [52], both individually and collectively. Most decision-makers, managers and academics accept that change is unavoidable. Research indicates, however, that only one-third of all change initiatives may achieve any success [53,54]. Moreover, according to Applebaum (1993) there is a great risk in failed change attempts as these may result in a sharp loss of motivation, satisfaction and commitment of participants [55]. This clearly implies the importance of a thorough understanding of the change process and its inherent consequences, focusing in the case of this research specifically on social learning processes.

For over half a century, researchers have attempted to provide insight into change processes and their dynamics with the aim to help organizations successfully implement change. This has resulted in a variety of theories that have been developed to understand and predict processes that organizations go through to implement change [56–59]. In a review of organizational change management research conducted during the 1990s, Armenakis and Bedeian (1999) indicated that four factors are common to all change efforts, while shaping reactions to these efforts: (a) *content* factors; (b) *context* factors; and (c) *process* factors; as well as (d) *individual attributes*. These key factors to the management of change processes have also been highlighted in academic literature related to water management practices in the Netherlands [e.g. [61,62].

2.1. (a) Content Factors–What is being changed?

Content factors refer to what is being changed or the type of changes being implemented. Sometimes change is deliberate, whereas some times change unfolds in a more spontaneous and unplanned way, e.g. when external factors influence the change, such as a crisis event. A number of authors [e.g. [63,64] distinguish changes from those having a severe impact on the lives of those involved, to changes where the impact is much less threatening. DeVos and Buelens (2003) emphasize that different types of changes have differing impact on attitudes of those involved towards the change content. Different researchers have adopted similar dichotomous distinctions about change content [e.g. [65–67]. However all these descriptions of different types of change imply that change differs in scope and focus, as well as to the degree with which it impacts, for example, a social-ecological system. To identify the character of a proposed change can provide a sense of how difficult the introduction of any particular initiative might be and how much disturbance to the status quo it might generate [68–70].

2.2. (b) Context factors - Why is the change successful or not?

Context factors may be described as pre-existing forces and conditions in the external and internal environment of a governance system that impact the effectiveness of the system [71,72]. These factors can either complicate or facilitate the implementation process of strategies or concepts. *External context* factors may be defined as those factors and forces over which organizations or a governance system has little control. Instead changes are often made in response to such demands [72]: e.g. crisis events; climate

change and uncertainties; governmental deregulation; or legislative and technological changes. *Internal context* factors may include, for example, levels of resistance or openness in attitudes toward a proposed change, levels of inter-stakeholder conflicts and tension, available knowledge resources, etc. [20,62,73]. Conditions of the internal context can explain the general attitude or readiness towards change [74]. For example, people in organizations or a system driven by politics or inconsistent leadership, will have a different attitude towards change than those who can rely on an open and strong leadership with clear goals related to change [53]. Also the culture and decision-making climate of organizations in directing and motivating people [75] affect openness to change. Moreover, a system's prior change history has impact on internal contextual issues [60].

2.3. (c) Process factors - How is the change implemented?

Process factors provide an indication of how change is organized and refer to actions and directions taken during the planning and implementation of a proposed change [72]. It refers to the way leaders introduce change as well as guide the change process and how cooperation and decision-making is organized. The way in which change is planned and implemented affects attitudes of individuals involved in the change process [58,76,77]. Research has indicated that participation is a central variable to increasing acceptance and success of change [77–79]. Walker *et al.* (2007) emphasize that people involved must believe that their opinions have been heard and given respect and careful consideration.

2.4. (d) Individual attributes - Who is involved and affects the change process?

Each change process involves a wide variety of individuals with specific characters and mindsets that determine their attitudes and behavior towards change. Individual attributes refer to micro-level factors relating to the reactions to change efforts by stakeholders and individuals involved. Attitudes and behaviors of individuals towards intended change ideally goes from an initial readiness, to adoption and finally institutionalization [56,59]. Readiness occurs when the external and internal context (the environment and structure) as well as the stakeholders' attitudes is non-resistant and open to the proposed change. Substantial empirical work examined the influence of personality characteristics in coping with change [79–82]. There is strong evidence to believe that individuals might react differently to the same change because of characteristics of change agents as well as those of their own [76].

Damonpour (1991) suggests that change success is ultimately determined by a fit between the different content, context, process and individual factors. These factors are all interconnected and should ideally all work towards the desired change. In this light, it should be recognized that some factors may be easier to change in the short-term and may eventually trigger required changes also in other factors that may be more difficult to change in the short-term.

3. Conditions for Double and Triple-Loop Social Learning

Sustainable land and water resources governance includes dynamic, problem solving processes in which individual and group-level learning about and reflection upon social-ecological change needs to be an essential component [83,84]. As highlighted in the previous section, learning is fundamentally about change, in particular the 'act or process by which behavioral change, knowledge, skills, and attitudes are acquired' [85]. Managing such change processes in complex environments requires purposeful and systematic facilitation of social learning processes among a variety of actors and stakeholders at and across a variety of levels and scales [6,86]. To analyze and understand the dynamics of such multi-level, multi-scale and complex governance systems may provide a considerable challenge.

In this section the meaning of multi-loop social learning processes is described based on a review of recent theoretical literature on the concept of double- and triple-loop learning in the context of land and water resources management. This section also provides a literature review of lessons learned and insights from recent empirical research on multi-loop social learning in the context of land and water resources governance. The discussion in section 1.2 is linked to this review and a preliminary framework is proposed that provides insight into what conditions are conducive to successfully facilitate double- and triple-loop learning.

3.1. What is Multi-loop Social Learning?

Higher-order or multi-loop social learning involves not only participation or learning in a group setting [87], it involves 'understanding the limitations of existing institutions and mechanisms of governance and experimenting with multi-layered, learning oriented and participatory forms of governance' [88]. In other words, multi-loop social learning processes entail exploratory and reflexive search processes (with different levels of intensity and scope) that provide opportunities to share diverse understandings and negotiate social change [41]. A vertical and horizontal integration of ideas and practices (linking personal and local behaviors to outcomes at broader scales) may help to gain a deeper understanding of different knowledge domains and traditions [18,23].

In the context of sustainable land and water resources management, the concept of multi-loop social learning has been associated with changes in governance norms and protocols [15,28,89,90], while involving actors and stakeholders that go far beyond the established resource governance regime [28,91]. The reflexive process of multi-loop social learning is described as a series of learning cycles–often referred to as single-, double- and triple-loop learning–that may eventually result in fundamental changes in behavior [21,27,91–93]. In the context of land and water resources management, such reflexive processes can be a crucial driver for social change as it can help reveal how theoretical, cultural, institutional, and political contexts affect learning processes, actions and values [94,95].

The concept of multi-loop social learning originates from the work of Argyris and Schön (1974) that is based on research into organizational behavior. Social learning has been conceptualized as a multi-layered and iterative process of examining actions, assumptions/values and learning processes. Argyris (1978) refer to this as multi-loop learning, involving single-loop, double-loop and triple-loop learning [96]. They describe single-loop learning as focusing on correcting errors by changing routine behavior, and double-loop learning as facilitating such corrections by examining underlying values and policies within an organization/system. Triple-loop learning includes 'designing norms and protocols that govern single- and double-loop learning' [97]. King and Jiggins (2002) explain that single-loop learning generates knowledge from doing, whereas double-loop learning explores the underlying values and assumptions behind our knowledge and learning. Triple-loop learning is described by these authors as a type of meta-learning reflecting on the processes by which learning has taken place.

In the context of sustainable land and water governance, single-loop, double-loop and triple-loop social learning can be described as follows [e.g. [1,28,91]:

3.2. Single-loop learning–Are we doing things right?

Single-loop learning can be described as '*following the rules*' while trying to correct an unacceptable outcome or result. This

type of learning can also be referred to as learning new skills and capabilities through incremental improvement, doing something better without examining or challenging underlying beliefs and assumptions (Incremental Learning)

3.3. Double-loop learning–Are we doing the right things?

In double-loop learning, individuals and groups reflect not only on whether deviations have occurred and how to correct them, but also on whether the *'rules'* should be changed. It may involve *'breaking the rules'* to ensure a problem or issue does not re-occur by refining or fixing the framework that governs the actions. *'Thinking outside the box'*, creativity, and critical reflection may help actors to understand why a particular solution works better than others in solving a problem or achieving a goal. Double-loop learning occurs by fundamentally revisiting and reshaping underlying assumptions and patterns of thinking and behavior (Reframing).

3.4. Triple-loop learning–How do we decide what is right?

Triple-loop learning involves reflexivity about the 'rules' (not only on whether the rules should be changed), or meta-learning on single- and double-loop learning processes. This kind of meta-learning is about learning how to learn; why individuals and groups learn the way they learn; and what norms, values, paradigm guide their learning and decision-making processes. Triple-loop learning may therefore involve a process of transformation by creating a shift in context or perspectives. Ultimately, this kind of learning may lead to a redesigning of existing governance norms, protocols and structures (Transformational Learning).

The outcomes of such multi-loop social learning processes (see Fig. 1) may include changes to everyday practices (single-loop learning), changes in behaviors and values (double-loop learning), as well as institutional changes, such as changes in structures, policies, programs, rules and decision-making procedures (triple-loop learning).

As visualized in Fig. 1, triple-loop learning involves the same reevaluation of assumptions and models as double-loop learning but considers additionally whether to alter rules for decision-making and fundamental changes in governance systems. Such multi-loop social learning processes may lead to a transition of actor and social networks where, for example, new actor and stakeholder groups come into play, boundaries and power structures are changed, and new regulatory frameworks are introduced [1,28,91].

According to Berkes (2009), collaborative structures that support these multi-loop social learning processes require at least the following three key elements: (a) *horizontal interaction* among stakeholders at different scales (boundaries); (b) *vertical interaction* of communities with actors at other levels; (c) and *iterative social learning* cycles (i.e. single, double and triple-loop learning). Multi-loop social learning processes are largely influenced by the governance system in which they are embedded and are assumed to occur at the following levels [3,21]:

i. **Macro-level:** at the level of change in governance structures - the governance and societal structural conditions that are characterized by for example cultural values, governance regime or power structures;
ii. **Meso-level:** at the level of change in actor networks - the actors in the water management regimes consisting of more or less organized stakeholder groups, for example authorities, who may partly engage in bilateral interactions;
iii. **Micro-level:** at the level of processes between participating stakeholders in collaborative learning processes - the multi-party collaboration processes in which representatives from different stakeholder groups interact.

Although single-loop learning may be sufficient when it comes to low levels of complexity, when levels of complexity and uncertainty in collaboration and of the issues involved are high, double- and triple-loop learning are required [28,89,90]. Regarding double-loop learning, Pahl-Wostl (2009) emphasizes the importance of recognizing that any progress would be constrained if individuals, organizations or networks would revisit and change basic values and beliefs on a frequent basis. On the other hand, there will also be no innovation or progress toward more sustainable land and water governance unless basic values and beliefs are revisited when required. In addition to the re-evaluation of assumptions and values of double-loop learning, triple-loop learning cycles include a consideration of whether or not to alter rules for decision-making at the meso-level and fundamental changes in governance systems at the macro-level.

Pahl-Wostl (2009) notes that double-loop learning may at times only be effective in combination with triple-loop learning while dominating frames of reference are often influenced to a large extent by the structural context. In other words, triple-loop learning may be needed in order to effectively guide collaborative processes and affect required changes in values and beliefs. It should also be noted that when looking at changing formal governance structures, macro-level decision-makers may have the power to change these structures; however, informal and cultural structures are rather shaped and reshaped at the local level through daily practices and interactions. Ultimately, social learning processes will remain at the level of non-binding discourse (double-loop learning) without leading to major structural changes unless a conducive process is developed that supports an extended actor network, codification of new routines and practices or formalization of new rules [3,21].

Linking specifications of double- and triple-loop learning to the discussion in section 1.2, one could state that for double-loop learning to take place, changes must occur mostly related to the way that a change/learning process is organized (process factors) as well as who are involved in this process (individual attributes). While triple-loop learning naturally follows double-loop learning, it would require the same changes as double-loop learning, and in addition, it would also require changes to take place within the internal and external context. Social learning in the context of sustainable land and water governance has so far only–if at all–entered the stages of double-loop learning [21,99]. It is crucial, therefore, to understand which kinds of processes and conditions support moving beyond single-loop learning. Not much effort has been put into defining how to achieve successful multi-loop social learning processes in a practical sense [1,25–27,100].

3.5. What does Multi-loop Social Learning require?

Multi-loop social learning generally involves complex multi-actor and stakeholder networks that are characterized by multiple differences in goals and interests playing out at different levels and scales [21,49]. It is therefore important to recognize that such multi-loop social learning processes are embedded in a web of power and trust dynamics [6,101–104]. Although the framework of content-context-process factors and individual attributes may offer a useful framework to consider important conditions for multi-loop social learning, it should be noted that when assessing these factors it is crucial to consider the complexity and challenges that come with multi-stakeholder learning for land and water governance. In such context, stakeholders often have very different, high stakes and the major challenges become how to tackle such multi-stakeholder learning at pluri-centric and multi-level scales. Cash et al. (2006) highlight that there is still relatively little understanding of the dominant mechanisms of cross-scale interaction, especially when analyses go beyond the more conventionally

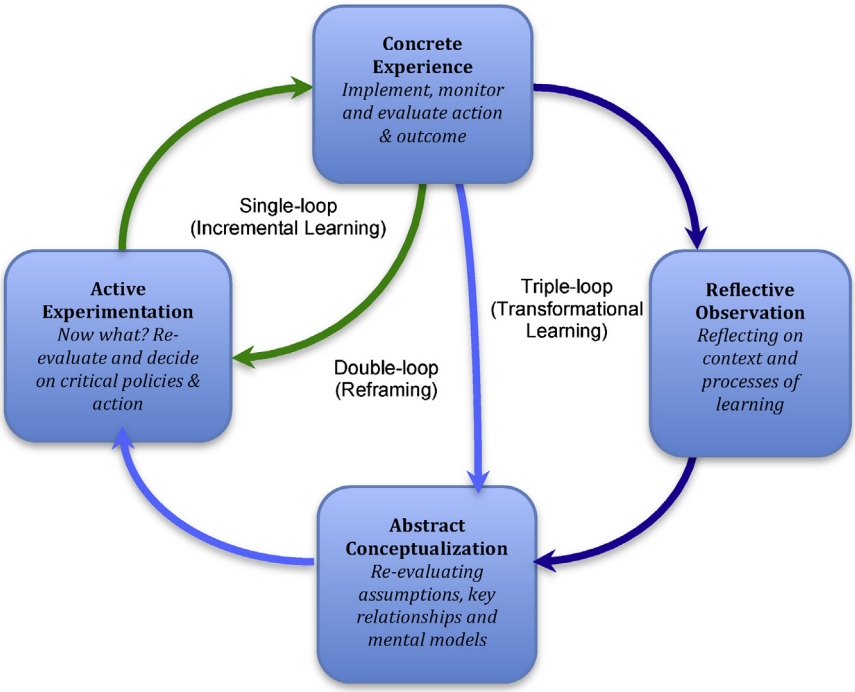


Fig. 1. Different pathways and outcomes of single–, double-and triple—loop learning (adapted from institutional learning cycle presented by Folke et al.2009:15, based on Kolb's experiential learning cycle, Kolb 1984).

studied spatial, temporal, and jurisdictional scales. These authors also emphasize that those systems that more consciously address scale issues and the dynamic linkages across levels are ultimately more successful at assessing problems and finding solutions that are more politically and ecologically sustainable.

The remainder of this section builds on earlier empirical work as well as theoretical notions from more recent scientific literature on sustainable land and water resources governance and the implementation of multi-loop social learning processes [e.g. [1,21,26,41,49,84,87,99,105–108]. Lessons learned have been drawn from this literature and related case studies and have been synthesized in this section into the different main categories of change factors: content, context, process factors and individual attributes. The last part of this section offers a summary in the form of a table that visualizes these lessons learned into a preliminary framework for the effective facilitation of double- and triple-loop social learning processes in the context of sustainable land and water governance.

(a) Content Factors–What is being changed?

As mentioned, content factors refer to what is being changed or the type of changes being implemented. This change content differs in scope and focus, as well as to the degree with which it impacts a social-ecological system. In other words, the character of the change content 'drives the show' and will primarily determine the amount of disturbance a particular intervention or initiative may generates to the entire learning process. The concept of multi-loop social learning has as its central hypothesis that the management of content (in this case the sustainable management of land and water resources) and social involvement is strongly interdependent and cannot be separated [3,21]. The type of change that is needed for a transition to more sustainable land and water governance requires in many cases a change of a more transformational and radical order [109]: involving a shift in underlying beliefs and assumptions made, both on an individual as well as a collective level (i.e. double- and triple-loop learning). In reality, however, the move towards sustainable governance has often been more incrementally: through a step-by-step movement toward a system ideal [72]. This may indicate that the way different initiatives have attempted to achieve more sustainable forms of governance have perhaps not been effective for the type of change that is required [105,110]. In many different cases, common sets of barriers have been shared that may point to a wider, underling problem–that of translating science-based management concepts and theories developed by experts and academics into practice.

Effective implementation of sustainable management concepts and approaches for land and water resources, as well as improvement of their theoretical domain, may depend on a more bottom-up approach [111]. The empirical evidence points to the issue that required change may often be implemented in a top-down manner, highlighting that in land and water resources management policy makers still give considerably more attention to policy development than to policy implementation [16,112]. The consequences of even the best-planned and supported policy initiatives, however, depend eventually on what happens as individuals throughout the policy system interpret and act on these policies [16,113,114]. The starting point for drawing up sustainable land and water policies and action plans should be with *locally identified problems and needs, while developing deeper understanding of the way individual attributes influence the implementation process and ongoing iterative relationships between different stakeholder groups*.

(b) Context factors - Why is the change successful or not?

As described in Section 1.2 context factors can be described as pre-existing forces and conditions in the external and internal environment of a governance system that impact the effectiveness of the system, and that either complicate or facilitate any change process. Policies and plans regarding the management of land and water resources are generally developed and implemented in different types of contexts, ranging between periods of significant change and periods where systems are essentially stable [63,64]. These different contexts and their change agendas may have very different bearings on possible outcomes of policy development and

implementation processes. Decisions to undertake major policy changes may be more easily undertaken during periods of significant or abrupt change, as changes tend to be slower and more incremental in periods of relative system stability [64].

External context factors are often difficult to control by a specific governance regime, and may offer strong drivers or catalysts to change interventions and processes. Empirical evidence indicates clearly that **crisis events** (periods of abrupt change) are often strong drivers to change and multi-loop social learning processes. Such crisis events may instigate, for example, the **political support and buy-in** as well as the **supportive legislative changes** that are required to bring about required change [8,105,106,108,115]. Another important factor that can support a change process is the availability of **external funding and support instruments** from a national and regional level. Johanessen and Hahn (2013), for example, describe how 'national financial and expert support for sustainable land and water resources management is insufficient', and with 'unrealistic demands on local levels that are often left on their own to make important decisions and experiment with adaptive measures, exposing them afterwards to criticism'. In this light, longstanding laws and policies, court rulings, powerful government agencies, and interest group coalitions with vested interest in retaining the existing system of laws, budget allocations, and bureaucratic structure pose a significant challenge to multi-loop social learning processes [99].

The *internal context* of a change process includes those factors that explain a general attitude of resistance or openness towards a proposed change (e.g. levels of inter-stakeholder conflicts and tension, available knowledge resources, levels of leadership with clear goals related to change, culture and decision-making climate of organizations in directing and motivating people, prior change history). Although internal context factors are very closely related to process factors (as described later in this section), the difference can mostly be explained by the fact that internal context factors are more or less pre-existing forces and conditions within the internal environment of a governance system that directly impact the effectiveness of the system [71,72]. In other words, internal context factors relate to the institutional structures and framework in which change or learning processes are taking place. Process factors, on the other hand, provide an indication of how change and learning processes are being organized and refer to actions and directions taken during the planning and implementation of a proposed change [72]. Ultimately, the pre-existing forces or conditions (external and internal factors) are often much harder to change in the shorter term than process factors.

In the light of external and internal context factors, Pahl-Wostl (2009) points out how many land and water resources issues are a direct or indirect result of certain governance failures such as corruption, a lack of efficiency and effectiveness of existing structures, and sectoral fragmentation. Resource governance is defined here as the system of formal and informal rules that steer how humans interact with land and water resources at all levels of social organization [23,99].

When it comes to the sustainable management of land and water resources, actors and stakeholders within the governance system often have largely differing perspectives, values and (social) power bases which may lead to one or more groups dominating the outcome of change processes [21,49,87,99]. Dyball *et al.* (2007) highlight how the diversity of knowledge and values in any sustainability situation demands **horizontal and vertical integrated cooperation structures** through polycentric or networked governance [21,107,116]. Ostrom (2001: 2) defines polycentric systems as "the organization of small-, medium-, and large-scale democratic units that each may exercise considerable independence to make and enforce rules within a circumscribed scope of authority for a specific geographical area". In the process of developing sustainable land and water management strategies the responsible decision-making units would need to involve local, as well as higher, organizational levels and aim at finding a balance between decentralized and centralized control [107,117,118].

Wals *et al.* (2009) highlight this by stating the importance of new initiatives and responsible units to connect and collaborate with 'existing informal networks or processes, as these are often made up of enthusiastic and creative people' (2009: 19). To avoid 'disjointed learning' as well as the creation of 'innovation elites'–a small energized group that is way ahead of the rest and therefore out of reach - the core group of 'change agents/learners' will need to communicate effectively with those actors/stakeholders they more or less represent [119]. In this context, it is crucial to recognize the importance of establishing **innovative learning structures** in the form of partnerships or networks that can offer transparent and democratic participatory platforms for allowing a polycentric, broad and horizontal stakeholder participation in land and water management activities [21,36,51,87,120–122]. Vertical and horizontal integration of ideas, knowledge, experiences and practices (linking personal and local behaviors to outcomes at a broader scale) may be achieved through such learning platforms that include a strong **commitment to ongoing multi-loop social learning** [41,49]. These learning partnerships have also been referred to as 'bridging organizations' that provides a 'polycentricity' of diverse, redundant organizations, coalitions, and networks that facilitate sustainable governance [98,123–125]. Multi-level systems, cross-scale interactions and informal networks connecting actors and stakeholders at multiple levels are crucial for multi-loop social learning [107,121,126,127].

Multi-loop social learning goes much further than just learning in a group setting, it involves 'understanding the limitations of existing institutions and mechanisms of governance and experimenting with multi-layered, learning oriented and participatory forms of governance' [88]. Addressing challenges posed for the sustainable governance of land and water resources requires, therefore, a **sound knowledge base and (technical) capacity** at both national and local levels to understand learning and change in multi-level governance regimes [3,12–14,106]. An important mechanism to foster multi-loop social learning is to have a driven **emergent leadership** (consisting of technically competent actors and stakeholders) with a **clear vision** that begin to challenge the existing assumptions and act as a persistent driving force to facilitate and coordinate the development of new knowledge, infrastructure and various inputs from other actors and stakeholders [105,108,119]. These self-organized groups enable more **advanced information management** through joint fact-finding, open and shared information sources, and flexibility and openness for experimentation, while visualizing a direction towards improvement. They also often have in-depth knowledge about existing social structures, power networks and power dynamics [42,106,122].

In a number of sustainability studies [e.g. [34,49,128,129] the **regional scale level** has been considered as the most crucial level to deal with sustainability management issues. The reason for this is that at this level the human and natural systems interact the most intensely, and regional levels tend to hold a specific capacity for generating new knowledge created through multi-actor innovation networks [130]. Also working at this level may bring a clear link between national and local levels, and a balance between top-down and bottom-up approaches to the sustainable management of land and water resources [16]. Pekkarinen and Harmaakorpi (2006: 410) note "the real competitive advantage of regional innovation networks is based on their ability to create knowledge in a collective and interactive learning process". While Sol *et al.* (2012) point out that some of the advantages to a regional approach are: (a) regional actors have access to localized knowledge within the region that can support the identification of promising directions for

sustainable development; (b) a regional approach allows the involvement of actors with a strong power base and capacity to implement new insight and actions emerging from a social learning process [128].

Although a broad actor and stakeholder diversity has been widely regarded as an important basis for multi-loop social learning [e.g. [1,26,45,131], such heterogeneous multi-actor innovation networks may also form a barrier to effective learning processes. Particularly, because they involve a wide variety of actors and stakeholders with often conflicting values and interests, as well as diverging perceptions of the complex sustainability issues involved [42,132].

(c) Process factors - How is the change implemented?

To achieve multi-loop social learning for sustainable land and water governance, Dyball et al. (2007) emphasize the importance of 'understanding system behavior through active monitoring of and feedback from the effects and outcomes of certain actions and decisions' [133]. These authors explain that **system orientation and system thinking** offers a powerful way to develop a much greater awareness and understanding of change process dynamics, including relationships and interactions, that take place in a complex context that is typical of human-environment interactions [27,41].

Although it is important to understand the context in which change is introduced, empirical research indicates that actual change is more likely to happen (in shorter to medium term) in the way change processes are organized and facilitated [8]. *Process factors* refer to actions and directions taken during the planning and implementation of change/learning processes and have a strong impact on the attitudes of participants towards the proposed change (e.g. how is change introduced and facilitated by leaders, how is cooperation and decision-making organized, how is the change process planned and implemented, are key stakeholders directly participating in these processes, and do they feel respected and heard). Ultimately, the success of change processes depends largely on whether the proposed change and its consequences are embraced by the multitude of agencies and stakeholders involved. When considering process factors that are supportive to multi-loop social learning, it is crucial to develop understanding of how to tackle and address multi-stakeholder learning at pluri-centric and multi-level scales. Cash et al. (2006) identify pervasive and difficult cross-scale and cross-level interactions in managing the environment, and highlight the importance of taking into account these dynamics when looking at human-environment systems. Common social and institutional responses to address such complex challenges of scale and cross-scale interactions include: (i) institutional interplay, (ii) co-management, and (iii) boundary or bridging organizations [134]:

Institutional interplay in cross-scale and cross-level contexts can be highly asymmetric or relatively balanced. Networks at different levels may use a range of mechanisms to develop appropriate cross-level mechanisms of interplay, such as the development of international and regional networks of community-based organizations and advocacy groups [116]. Inviting a wide and diverse group of actors and stakeholders into a learning process may facilitate the development of new and strong learning partnerships through which participants engage in land and water management activities [21]. Also, a variety of different types of **extended participation and engagement** (e.g. coercing, informing, consulting, enticing, co-creating, co-acting) are required during a change process depending on the joint learning and management objectives that have been set [135]. Participatory approaches that are consistent with multi-loop learning may provide a much greater understanding of the contexts, power dynamics and values that affect land and water resources management [27,41].

Successful **co-management** between different actors and stakeholder groups often arises from 'adaptive, self-organizing processes of learning-by-doing rather than from an optimal power-sharing across levels' [5] and should include: (a) building vision, leadership, and trust; (b) enabling legislation to create political opportunities; (c) monitoring the environment; (d) combining different kinds of knowledge; and (e) supporting collaborative learning [121]. Ultimately, sustainable land and water governance requires **collaboration** of all decision-making sectors, including different forms of evidence and knowledge traditions. Community consultation has become considered a required practice in this context, although full collaboration is often not met. While forging collaboration, it will be important to embrace possible conflicts and to harness this force through **negotiation**. In negotiation, rules of dialogue will need to be agreed upon to ensure that the diversity of interests can be expressed and considered, and power imbalances and conflicts addressed [27,41].

Cash et al. (2006) highlight that it is important to keep in mind that knowledge is often held, stored and perceived differently at different levels, which is caused by the differences across levels about what is perceived as salient, credible, and legitimate knowledge, or what is perceived as the important scale or level of the problem. Organizations that explicitly focus on addressing this challenge are known as **boundary organizations** or **bridging organizations** [5,134] that can play an important role in bridging different arenas, levels, or scales while facilitating co-production of knowledge. This role can be formalized in organizations specifically designed to act as intermediaries or present in organizations with broader roles and responsibilities. The following characteristics of such organizations are important [136]: (i) accountability to both sides of the boundary; (ii) the use of "boundary objects" such as maps, reports, and forecasts that are co-produced by actors on different sides of a boundary; (iii) participation across the boundary; (iv) convening; (v) translation; (vi) coordination and complementary expertise; and (vii) mediation.

Horizontal and vertical **integration and synthesis of knowledge** are necessary for effectively facilitating multi-loop social learning processes [41]. It is crucial that cross-level linkages are developed that allow access to information and provide benefit by linking agents through the use of this information [116]. Access to externally validated information makes information trustworthy and the process of information gathering and analysis more legitimate. Access to credible science originating at different levels has been central to strategies of environmental advocacy groups as well as government agencies in a host of conflict situations [126].

Boundary or bridging organizations may also play critical roles in mediating the differences inherent in conflicting perceptions and interests. Leadership through such organizations is important for the development and communication of a common vision for the management of a particular ecosystem that can provide a clear direction to the cross-scale or cross-level process. It is likely that without this cross-level leadership and change agents the necessary social and institutional structures and processes to deal with cross-level dynamics will fail to emerge [134]. Empirical evidence suggests that formation of informal networks–also referred to as 'adaptive networks' [122] or 'shadow networks' [121]–may be very essential during the beginning stages of a change process [21]. Key leaders and informal networks are mechanisms that may prepare a system for change through exploration of alternative system configurations and strategies for different future directions.

Furthermore, **reflection and reflexivity** are essential elements to multi-loop social learning processes [41]. Reflection as an integral part of learning and change processes reveals in more depth the ways in which both the external and internal context as well as individual attributes of those involved affect learning and change processes, actions and values [5,94,137]. An **intentional approach**

to learning must be taken by actively promoting organizational learning and critical self-reflection in participants through, for example, 'lessons learning' meeting and 'learning' workshops that promote broad community dialog about what was learned [87]. Different mechanisms, such as adaptive management, and collaborative monitoring and evaluation, may catalyze reflexivity and help to reveal otherwise unknown or unrecognized issues [86,87,138]. Reflexive processes take place on: (a) the individual level through setting of goals and monitoring of process and outcomes; (b) the interpersonal level through e.g. briefing and debriefing within groups; (c) the community level through creation of a common vision and identifying priorities and performance indicators; and (d) the social level through evaluating and auditing impacts of laws, regulations and markets [27,41].

A number of authors [e.g. [21,41,49,108,119] stress the importance of providing an **enabling and democratic environment** or structure for multi-loop social learning processes that are characterized by **informal and open discourse**, repeated interactions, trust, collective meaning and sense making, open communication, unrestrained thinking, constructive conflict facilitation, as well as a sense of ownership and commitment regarding the learning process, solutions and outcomes. While differences of views and perceptions may lead to conflicts, Bohm (1996) emphasizes the importance of the **rules and principles of dialogue**. These rules include a commitment to the integrative process, listening and speaking without judgment, identification of underlying assumptions, acknowledgement and respect for other contributions and ideas, recognition of differences between inquiry and advocacy, relaxing need for any particular outcomes, listening to self and speaking for self when necessary, and going with the flow [27,41]. Open and innovative discourse is of great importance while more formalized settings generally keep actors stuck in defending entrenched positions and bargaining rather than collaborating and learning together [3,5,122].

Trust between stakeholders is essential and can be eroded by e.g. differences of opinion or misunderstanding. **Good will, mutual understanding and trust** are prerequisites for reaching common understanding and goals, but to build up trust, good will and mutual understanding costs time and can easily be broken down [105]. A study by Sol *et al.* (2012) shows, for example, that 'a slow decline of commitment resulted in a sudden decline in mutual trust later on' (2012: 41). In this light, Sol *et al.* (2012) emphasize the importance of effectively facilitating multi-loop social learning and the establishment of dynamic and constructive social relationships for the development of trust and commitment throughout these learning processes. Commitment in this context does not refer only to passion or motivation towards an initiative, but also to the amount of resources such as time and money that are made available, and can be distinguished by commitment on a personal as well as an organizational level [49]. Trust can be build through an equal distribution of decision-making where people's issues and concerns are adequately addressed. Distrust, however, arises in a stakeholder process through misperceptions of other parties, labels that people put on other people, and (assuming) hidden agendas. This distrust can lead for example to exclusion of parties, not sharing of necessary information, not believing information that is shared, lack of giving support, keeping cards to yourself [111].

Finally, empirical research indicates that for the effective facilitation of multi-loop social learning processes it is beneficial that: (1) issues are considered important for and decided by key actors and stakeholders; (2) different stakeholders depend on each other to reach their goals; (3) knowledge is incomplete or dispersed amongst different stakeholders; and that (4) there is little agreement on the problems at stake. Whether the way to organize these learning processes is one of institutional interplay, co-management, boundary/bridging organizations, or alternatively a combination of these possible mechanisms, any solutions must recognize the multi-level challenge to sustainable land and water governance. It is therefore of utmost importance to find a suitable middle path (between top-down and bottom-up approaches) that addresses the complexities of multiple scales and multiple levels [134].

(d) Individual attributes - Who is involved and affects the change process?

Another type of factors that should not be ignored in change and learning efforts are individual differences or attributes among change/learning agents and targets [140–142]. Judge et al. (1999:107) suggest that change success can depend in part on the 'psychological predispositions of individuals experiencing change'. Although change is often aimed for structures, hierarchy, systems and technology, Schein (1980) states that it is mediated through individual change [143]. He emphasizes that many change efforts fail because the importance of the individual, cognitive-affective nature of change is underestimated. People may often have a confirmation bias causing them to search for and selectively process information confirming their beliefs [144,145], and knowledge may be neglected that contradicts dominating assumptions and potential threats or needs for change may therefore not be recognized [3,5,21,42].

There is strong evidence to believe that individuals might react differently to the same change because of characteristics of change agents as well as those of their own [49,76,79–82]. Armenakis et al. (1993) emphasize the importance of internal change agents (i.e. leaders and managers) as individuals might react differently regarding the same situation within a change setting due to the managers and leaders' attributes. In other words, Individuals and their attributes and characteristics form the basis through which change processes are manifested [72]. Substantial empirical work examined the influence of personality characteristics in coping with change [79,82]. For example, individuals highly **tolerant of ambiguity** [80] should be better equipped to handle the uncertainty associated with changes [82]. Similarly, individuals high in **openness to experience** [146] and high self-monitors [147] should react more positively to change efforts [79]. Several authors [e.g. 21, [49,108] stress the importance that those involved have a **capability for critical self-reflection,** which is crucial to multi-loop social learning and transitions toward more sustainable resource governance approaches. Another important individual characteristic is **locus of control**: the individual's perception of his or her ability to exercise control over the environment [81].

Ultimately, it is about the mindset of those involved and how **flexible and open minded** they are in the process [111]. Hofstede claims that human nature is inherited with ones genes and interplays with culture to produce personality traits: 'a unique set of mental programs', some of which is learned and some inherited [148,149]. In line with the phases in a change process, the attitudes and behaviors of individuals towards intended change ideally goes from an initial readiness, to adoption and finally institutionalization [56,59,60]. It is stated that readiness occurs when the external and internal context (the environment and structure) as well as the individuals' attitudes are non-resistant and open to the proposed change. Subsequently, these individuals alter their attitudes and behavior conforming requirements for change to occur. And finally, the change becomes institutionalized: an integral part of behavior and attitudes.

Levels of resistance to change may be related to the level or scale of the intended change, assuming that the higher the scale of change, the more resistance such an initiative may bring [49,150–152]. Resistance to change is often caused by a loss of a stable state. A belief that certain constancy can be attained of central aspects of our lives rests strongly and deeply in human beings

Table 1
Drivers and conditions for double- and triple-loop social learning.

Double-loop and Triple-loop Social Learning			
Individual Attributes	Process Factors	Internal Context	External Context
Tolerance of ambiguity [80,82]	Promoting system orientation and system thinking [27,41]	Vertical and horizontal integrated cooperation through networked governance [21,108,113]	Crisis events, climate change and uncertainty [8,111,112,121]
Openness and commitment to change and learning [79,148]	Facilitating institutional interplay [107,108]	Innovative learning structures and partnerships [21,36,51,87,109,125,126]	Political support and buy-in [8,111,112]
Capability for critical self-reflection [21,49,79,114,149]	Extended participation and engagement [27,41,137]	Commitment to ongoing multi-loop social learning [41,49]	National and regional funding and support instruments [114]
Locus or perceptions of power and control [81,111]	Co-management through collaboration and negotiation [27,41,107,109]	Sound knowledge base and (technical) capacity [3,12–14,112]	Supportive regulatory frameworks [8,111,112,114,121]
Flexibility and open-mindedness [111,150,151]	Developing bridging organizations that facilitate integration and synthesis of knowledge [5,41,107,110,138]	Emergent leadership with clear vision [111,114,124]	
Reliable, consistent and respectful of others' viewpoints [49,148]	Facilitating ongoing reflection & reflexivity by embracing an intentional approach to learning [5,41,86,87,94,139,140]	Advanced information management [42,112,126]	
	Creating an enabling and democratic environment characterized by informal and open discourse [21,41,49,114,124]	Dealing with sustainability management issues from a regional scale level [34,49,131,132]	
	Following rules and principles of dialogue [27,41]		
	Building trust, good will and mutual understanding [49,111,]		

and may provide a defensive wall against uncertainties [153]. Schön calls this tendency *dynamic conservatism*–the fight to remain the same - and emphasizes that people must learn to understand, guide, influence and manage these transformations as well as become adept at reflecting and learning. Systems must become learning systems capable of bringing out their continuing transformation. In this process it is important to understand and communicate what demands are made on a person who engages in this kind of change and learning [153]. It should be noted that it is not realistic to believe that this resistance to change can be overcome either by ignoring this phenomena and just plowing ahead, or by trying to pacify it through e.g. motivational speeches or a quick hitting series of team meetings [21,105]. Instead more thorough attention must be paid to the cognitive and psychological conditions underlying the resistance to change [106,107]. Frequent and personal interactions may allow participants to get to know each other as individuals while demonstrating qualities such as reliability, commitment, consistency, transparency and respect for others' viewpoints [49,154].

Damonpour (1991) suggests that change success is ultimately determined by a fit between the different content, context, process and individual factors. These factors are all interconnected and interdependent and should ideally all work towards a desired change. In this light, it should be recognized that some factors may be easier to change in the short-term and may eventually trigger required changes also in other factors that may be more difficult to change in the short-term. To summarize this section above, effective multi-loop social learning requires and is driven by certain key elements and conditions, such as: e.g. working with complexity, fostering individual and collective learning, re-inventing institutions, dealing with conflict, shifting powers, innovative learning platforms and environments, enabling effective and open communication, and promoting collaborative leadership (see Table 1 for a complete summary of this section).

3.6. *The Premises of Virtual Learning Platforms*

In order to achieve more sustainable land and water governance, a transition is required in current water management regimes from changes in strategies and actions, in individual and collective beliefs and behaviors, and in management processes, to the establishment of entirely new organizations and structures. It is crucial, therefore, to move from more fragmented forms of governance to shared power and responsibilities, and pluri-centric as well as multi-level partnerships between public, private and civil society stakeholders/actors. As highlighted in section 1.3, several key conditions and affordances have been identified from recent experiences with and studies on multi-loop social learning in different settings.

It is clear that the generation and sharing of new knowledge and understanding is essential for the effective facilitation of multi-loop social learning processes [1,21,26,155]. Multi-loop social learning is not only about managing change processes, it is also about managing new knowledge; new understanding develops as a result of the changes involved. This is directly related to the building and learning of institutional and individual capabilities, as well as the mechanisms by which these capabilities are stored and transferred into decision-making and action [156,157]. One of the areas that may offer significant opportunities for effective and innovative ways of facilitating multi-loop social learning is related to the mode or mechanisms of social interaction through which the learning occurs, both in the way information may be transmitted and stored, as well as the deliberation of new knowledge, ideas and perceptions [1]. The use of digital and emerging technologies may offer an array of innovative opportunities to developing and transferring knowledge, building awareness, as well as connecting a (much larger) diversity of individuals and groups at different levels and scales, in combination with face-to-face interactions [38,158].

While highly complex and uncertain land and water management challenges require extended decision-making processes, concepts of the information society and electronic governance together with the practical deployment of existing, new and innovative digital technologies may become driving forces of these processes through virtual learning environments or platforms [63,159,160]. These technologies–that are embedded into every domain of human action–enable vast networks of people, organizations and communities, which vastly expand the possibilities of coordinated action and collaboration within and outside organizations, regions, countries and industries [161–164]. Snowden and Stanbridge (2004) emphasize how the digitalization of data brings an enormous array of possibilities and capacity for transferring,

Table 2
Potential of virtual learning platforms for effective facilitation of multi-loop social learning [38,158,188,.

Areas of Potential	Type of change factor	Description
For research and analysis of sustainability management issues	*Internal context:* Sound knowledge base and capacity; advanced information management; dealing with sustainable management issues *Process factors:* Extended participation and engagement; developing bridging platforms; integration and synthesis of knowledge; facilitating ongoing reflection and reflexivity	By offering a laboratory for experimentation that can produce a great deal of data, which may provide useful insights and produce new knowledge and understanding. The use of digital technologies may offer an array of innovative opportunities to developing and transferring knowledge, building awareness, as well as connecting a (much larger) diversity of individuals and groups.
To design innovative and alternative solutions to sustainability issues	*Internal context:* Dealing with sustainability management issues *Process factors:* Promoting system orientation and system thinking; facilitating ongoing reflection and reflexivity	By analyzing and assessing the possible consequences of alternative solutions in order to recommend a more sustainable course of action. Virtual learning environments can function as a virtual design studio useful to develop innovative thinking about alternative solutions to sustainability management issues, and to consider consequences of certain decisions and actions
To provide strategic directions	*Internal context:* Vertical and horizontal integrated cooperation; innovative learning structures; dealing with sustainability management issues *Process factors:* Facilitating institutional interplay; extended participation and engagement; building trust, good will and mutual understanding	By acting as a virtual practice space in which policy and decision makers can rehearse different strategies by including other players that can act as sparring partners for the policy decision makers, while playing the role of other stakeholder as opportunistically as possible
To foster conflict mediation and build consensus among actors and stakeholders	*Internal context:* Innovative learning partnerships *Process factors:* Facilitating institutional interplay; extended participation and engagement; collaboration and negotiation; creating an enabling and democratic environment; building trust, good will and mutual agreement	By putting the players around a virtual negotiation table. In this way the changes in attitude and the discovery of new opportunities for conflict resolution are eased by facilitating a fun and engaging space for interaction and collaboration among actors and stakeholders. Deep bonding experiences can be facilitated to build trust, resolve conflicts, and increase a sense of belonging
To facilitate virtual consultation forums and learning partnerships	*Internal context:* Innovative learning partnerships *Process factors:* Facilitating institutional interplay; extended participation and engagement; collaboration and negotiation; creating an enabling and democratic environment; following rules and principles of dialogue; building trust, good will and mutual agreement	By allowing active involvement of citizens and the public in policy-making processes that normally only include experts, managers and other decision-makers. This fosters equal access and a democratic environment for all actors carrying s diversity of views and opinions. It also provides a safer and more accessible environment to the wider public for more easer and open engagement and expressions of views and opinions
To clarify values and arguments	*Internal context:* Innovative learning partnerships; emergent leadership with clear vision *Process factors:* Extended participation and engagement; collaboration and negotiation; creating an enabling and democratic environment; following rules and principles of dialogue; building trust, good will and mutual agreement	By creating a virtual parliament, which makes it possible to make values and arguments more explicit. Virtual learning platforms can also be used to magnify positions and opinions of stakeholders so that, e.g. a game can be designed to reward players for quality and clarity of argumentation
To enable development and sharing of new knowledge and understanding	*Internal context:* Innovative learning structures; sound knowledge base and capacity; advanced information management *Process factors:* Facilitating institutional interplay; extended participation and engagement; bridging platforms; integration and synthesis of knowledge	By offering critical knowledge infrastructures to (global) societies for interaction, transformation of governance processes, as well as for the creation and diffusion of ideas, knowledge, and cultural practices that come with a wide set of actors and stakeholders. The digitalization of data brings an enormous array of possibilities and capacity for transferring, storing and processing of new data and information
To build new skills and capacities	*Internal context:* Sound knowledge base and capacity *Process factors:* Collaboration and negotiation; creating and enabling and democratic environment	By facilitating deep and meaningful learning of technical skills and other capacities related to, for example, self-confidence, negotiation and mediation skills, empathy, team-work as well as active and creative problem-solving skills

storing and processing of information, and the growing roles of virtual interactions and communities are dissolving boundaries between the real (offline world) and imaginary (online world). The Internet, mobile networks, and social media have become critical infrastructures to our global societies [165,166] and have become strong enabling factors and instruments for global interaction, transformation of governance processes, as well as for the creation and diffusion of ideas, knowledge, and cultural practices that come with a diverse set of actors [167–169].

With a growing digital lifestyle, it will become more and more the norm that learning processes and environments offer interactive, engaging, and dynamic processes through, for example, blogs, wikis, social networking, podcasts, online video, as well as simulations and virtual worlds [170,171]. The potential of virtual learning platforms for learning purposes is increasingly being investigated [172–176], in particular within the education and health sectors, as well as its use to enhance participatory processes [177]. The involvement of a wide variety of actors and stakeholders in decision-making and learning processes through digital technologies necessitates the skilled design of interfaces that can connect issues with intended audiences [178]. To achieve this, similar principles must be followed that also sustain new styles of hybrid or networked governance: congruency, a sense of trust, open communication, availability of resources, as well as knowledge sharing and co-production [19]. Participants will need to be encouraged to find their 'voices', respect the voices of others and begin to take risks in their thinking, and personal and professional lives [177].

The major strengths associated with virtual learning platforms are the potential to design and construct unique environments in which learners actively create and interact [161,164,179]. In other words, these virtual environments may offer great potential for reshaping facilitation of multi-loop social learning, communications, social interactions, and reframing of perceptions in a more innovative, safe and vivid manner. At the same time, they also present interesting questions surrounding themes such as cross-generational communications, identity exploration, cross-cultural exchange, problem solving, and deep dialogue [180,181]. As a matter of fact, some studies have shown that learning facilitated through, for example, games, simulations or virtual worlds may likely outperform more traditional forms of learning processes [168,182,183]. Devlin *et al.* (2012) suggest that virtual learning platforms can facilitate deep and meaningful learning of life skills such as self-confidence, negotiation and mediation skills, empathy, team-work as well as active problem-solving skills [184]. Such platforms can also offer a deep bonding experience between participants that helps to build trust, resolve conflicts, and increase a sense of belonging [185]. Fredrickson (2002), in turn, emphasize the role of these positive emotions in broadening people's capacity to learn and enhance their creative and innovative problem-solving capacities [186].

Virtual learning platforms - including for example social media, multiplayer social games, sophisticated computerized simulations, 3D engines and virtual worlds - have the potential to facilitate multi-loop social learning by storing, processing and transmitting new data and information; allowing diverse and geographically-separated communities equal access to a 'virtual negotiation table' to develop and share knowledge; and by providing opportunities to test and analyze the outcomes of novel management solutions [63,119,167,168]. They can be immersive, engaging, competitive, and purposeful, while offering risk-free opportunities to experiment with and evaluate innovative water management strategies and policies. It is expected that such platforms may expedite learning of the skills needed for effective engagement, including negotiation, mediation, teamwork and problem solving [185], and have the potential to be more successful in facilitating multi-loop social learning than traditional offline methods [168,170,174,182].

Although there are a significant amount of examples of the use of these virtual learning platforms to foster interactive learning in education, military and health, the land and water resources management sectors have only very recently begun exploring this potential [187–189]. In the context of land and water governance, virtual learning platforms developed to date are used principally to build awareness and develop a shared understanding of common problems and trade-offs [190]. Examples of recent interactive online learning platforms developed for the water sector include Aqua Republica, CauxOperation, the UVA Bay Game and the Climategame [187,191,192]. Several authors [e.g. 190, 191, [189,193] emphasize that more research is needed on design principles, exploring appropriate virtual learning platforms and tools for particular land and water issues, and assessing the impact of these platforms on social learning and collaboration for sustainable governance.

Although the use of digital technologies and virtual learning platforms have not yet been widely recognized within the environmental and natural resources sector, they have great potential to offer a safe and engaging space to learn, collaborate, find innovative solutions and make sustainable decisions regarding complex and uncertain land and water management challenges. Table 2 below summarizes the potential of virtual learning platforms (including virtual worlds, simulations and social games) for effective facilitation of multi-loop social learning, highlighting the different conditions and drivers that can be offered and developed through the use of such innovative platforms. Although individual attributes are not mentioned in the Table, each of the areas of potential uses of virtual learning platforms may affect the individual attributes of both change/learning agents as well as change/learning targets. Although these platforms may not have a direct impact on the external context factors (as described in Section 1.3), they may indirectly affect changes by stimulating an increased political support and buy-in to proposed change/learning efforts, as well as more supportive regulatory frameworks.

While virtual worlds, simulations and social or serious games may offer opportunities for transformative learning [194], studying the learning processes that are facilitated through these forums and platforms are essential to provide greater arguments and deeper understanding on how to design virtual learning platforms for effective facilitation of multi-loop social learning to achieve sustainable land and water governance.

4. Conclusions

While most of the studies highlighted in Section 1.4 refer to ICT facilitated education and skills learning in the education and health sector, it may be dangerous to extrapolate the findings of this literature on ICT supported learning to multi-loop social learning for sustainable land and water governance. The studies by Mayer et al. (2004), as well as Bots and van Daalen (2007), bridge this gap by elaborating on the potential functions of ICT games as tools in policy-making processes. Their work, amongst others, emerged from collaboration with Companion Modelers in Montpelier who designed participatory social learning processes for natural resources management, using a mix of virtual and non-virtual tools and discussion methods. Their articles do not refer to virtual platforms as means for facilitating social learning in natural resources management, but do note that ICT tools can have useful functions in a properly designed learning and policy making process. In this light, it will be important to review and assess in much greater detail the strong and weak points of various ICT tools. Although ICT tools may not be the ultimate solution for multi-loop social learning in our contemporary world, they may offer some

significant advantages when carefully used for certain functions in social learning processes.

Virtual learning platforms may, for example, provide opportunities to experiment with more hybrid and networked forms of governance, citizenship and new collaborative structures. Well-designed deliberative and coordinated learning processes may significantly improve stakeholder engagement and interaction as well as collective and sustainable decision-making processes. Additionally, for solving sustainable land and water management challenges, the focus becomes not only on including a wider set of actors and stakeholders, but resources, information and solutions may in fact be drawn and lessons learned can be shared from anywhere in the world. Interactive learning environments, including for example social media, multi-player social games, sophisticated computerized simulations, 3D engines and virtual worlds, may offer opportunities to see the systemic and long-term impact of actions and decisions in a very concrete and tangible form, thereby encouraging more responsible and sustainable behavior and long-term thinking. These tools also engage participants through a more 'fun' and 'social' dimension, thereby providing incentives towards coordinated action.

The aim of this paper has been to critically assess what conditions and affordances are conducive to multi-loop social learning in the context of sustainable land and water governance. The insights from this critical review confirms the potential of a 'learning ecology' or virtual learning platform for knowledge co-production, trust building, sense making, critical self-reflection, vertical and horizontal collaboration, and conflict resolution, while potentially serving as a facilitating platform between different levels of governance, and across resource and knowledge systems. To conclude this paper, a developmental research agenda is proposed to refine and improve understanding of multi-loop social learning processes and their effective facilitation through virtual learning platforms:

For the *effective design of virtual learning platforms* for sustainable land and water governance, the specific challenges of the development and use of tools (e.g. simulations and social games) for public policy development, awareness and coordinated action need to be further researched. Studying the multi-loop social learning processes that are facilitated through such forums may also provide greater arguments and deeper understanding on how to design these virtual learning platforms with the aim to facilitate multi-loop social learning. It will be important to develop a toolbox that supports the empowerment of a diverse and inclusive virtual learning landscape, where the most diverse set of ideas can be included, engaged and listened to.

It should be noted, that these virtual learning environments are not meant to completely replace existing systems; these interactive learning platforms that enable the virtual connection of a diverse and local, regional and global audience will need to be effectively linked or interfaced with direct and face-to-face interactions since both forums offer a different quality. Where face-to-face interactions allow more locally relevant questions and a more contemplative speed for local experts and stakeholders to present, deliberate and reiterate information and knowledge, wider-situated online interactions provide lower barriers for a much wider stakeholder involvement to generate and aggregate new and innovative ideas and solutions to land and water management challenges.

And finally, it is important, to assess in more depth what these platforms (including a diversity of digital tools and technologies) may be used for, as well as what the risks may be of delegating such vital decision-making processes to learning partnerships and self-organized networks, as well as the risk of some communities being left behind.

Acknowledgements

This study was funded by a Social Sciences and Humanities Research Council of Canada (SSHRC) Standard Research Grant held by Jan Adamowski.

References

[1] M.S. Reed, A.C. Evely, G. Cundill, I. Fazey, J. Glass, A. Laing, J. Newig, B. Parrish, C. Prell, C. Raymond, L.C. Stringer, What is social learning? Ecology and Society 15 (2010) r1.
[2] D. Armitage, R. Plummer, F. Berkes, R.I. Arthur, A.T. Charles, I.J. Davidson-Hunt, A.P. Diduck, N.C. Doubleday, D.S. Johnson, M. Marschke, P. McConney, E.W. Pinkerton, E.K. Wollenberg, Adaptive co-management for social-ecological complexity, Front Ecol Environ 7 (2009) 95–102.
[3] C. Pahl-Wostl, Transitions towards adaptive management of water facing climate and global change, Water Resources Management 21 (2007) 49–62.
[4] R. Ison, N. Roling, D. Watson, Challenges to science and society in the sustainable management and use of water: investigating the role of social learning, Environmental Science and Policy 10 (2007) 499–511.
[5] C. Folke, T. Hahn, P. Olsson, J. Norberg, Adaptive governance of social–ecological systems, Annual Review of Environment and Resources 30 (2005) 441–473.
[6] C. King, J. Jiggins, A systematic model and theory for facilitating social learning, in: C. Leeuwis, R. Pyburn (Eds.), Wheelbarrows Full of Frogs, Koninklijke Van Gorcum, Assen, The Netherlands, 2002, pp. 85–105.
[7] N.G.a.W.M.A. Röling, Facilitating Sustainable Agriculture, Cambridge University Press, Cambridge, 2000.
[8] W. Medema, B.S. McIntosh, P.J. Jeffrey, From premise to practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector, Ecology and Society 13 (2008) 29.
[9] J.I. Matondo, A comparison between conventional and integrated water resources planning and management, Physics and Chemistry of the Earth 27 (2002) 831–838.
[10] S.P. Simonovic, A shared vision for management of water resources, Water International 25 (2000) 76–88.
[11] R.A. Wurbs, Dissemination of generalized water resources models in the United States, Water International 23 (1998).
[12] E. Ostrom, Vulnerability and polycentric governance systems, Newsletter on the International Human Dimensions Program on Global Environmental Change (2001).
[13] E. Ostrom, Developing a method for analyzing institutional change, in: S.a.M.N. Batie (Ed.), Assessing the Evolution and Impact of Alternative Institutional Structures, Routledge Press, London, 2008.
[14] Young, O., Designing Environmental Governance Systems: The Diagnostic Method, Keynote at IDGEC Synthesis Conference, Bali 2006, 1.2007, pp. 9–11, Summary published in IHDP Newsletter, 2007.
[15] D. Armitage, M. Marschke, R. Plummer, Adaptive co-management and the paradox of learning, Global Environmental Change 18 (2008) 86–98.
[16] B.A. Lankford, Integrated, adaptive and dominial water resources management, in: C. PahlWostl, P. Kabat, J. Moltgen (Eds.), Adaptive and Integrated Water Management, Springer-Verlag, Berlin Heidelberg, 2008.
[17] R. Eberhard, C. Robinson, J. Waterhouse, J. Parslow, B. Hart, R. Grayson, B. Taylor, Adaptive management for water quality planning – from theory to practice, Marine and Freshwater Research 60 (2009) 1189–1195.
[18] R. Plummer, D.R. Armitage, R.C. de Loë, Adaptive comanagement and its relationship to environmental governance, Ecology and Society 18 (2013) 21.
[19] D. Armitage, R. de Loë, R. Plummer, Environmental governance and its implications for conservation practice, Conservation Letters 5 (2012) 245–255.
[20] D. Huitema, E. Mostert, W. Egas, S. Moellenkamp, C. Pahl-Wostl, R. Yalcin, Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda, Ecology and Society 14 (2009) 26.
[21] C. Pahl-Wostl, A conceptual framework for analyzing adaptive capacity and multi-level learning processes in resource governance regimes, Global Environmental Change 19 (2009) 354–365.
[22] I. Fazey, J.A. Fazey, D.M. Fazey, A. Learning more effectively from experience, Ecology and Society 10 (2005) 4.
[23] F. Biermann, M.M. Betsill, J. Gupta, N. Kanie, L. Lebel, D. Liverman, H. Schroeder, B. Siebenhuner, Earth system governance - People, places, and the planet, The Earth Systems Governance Project, International Human Dimensions Program, Bonn (2009).
[24] B. Siebenhüner, Learning in international organizations in global environmental governance, Global Environmental Politics 8 (2008) 92–116.
[25] G.a.F.C. Cundill, Monitoring in adaptive co-management: Toward a learning based approach, Journal of Environmental Management 90 (2009) 3205–3211.
[26] M.a.J.P. Muro, A critical review of the theory and application of social learning in participatory natural resource management, Journal of Environmental Planning and Management 51 (2008) 325–344.
[27] M. Keen, T. Bruck, R. Dyball, Social learning: a new approach to environmental management, in: M. Keen, V. Brown, R. Dyball (Eds.), Social learning in

environmental management: towards a sustainable future, Earthscan, London UK, 2005, pp. 3–21.
[28] L. Lebel, T. Grothmann, B. Siebenhuener, The role of social learning in adaptiveness: insights from water management, International Environmental Agreements-Politics Law and Economics 10 (2010) 333–353.
[29] T. Hahn, P. Olsson, C. Folke, K. Johansson, Trust building, knowledge generation and organizational innovations: the role of a bridging organization for adaptive co-management of a wetland landscape around Kristianstad, Sweden, Human Ecology 34 (2006) 573–592.
[30] C. Folke, J. Colding, F. Berkes, Synthesis: building resilience and adaptive capacity in social-ecological systems, in: F. Berkes, C. Folke, J. Colding (Eds.), Navigating Social-Ecological Systems: Building Resilience for Complexity and Change, Cambridge University Press, Cambridge, 2003, pp. 352–387.
[31] V.H. Dale, S. Brown, R.A. Haeuber, N.T. Hobbs, N. Huntly, R.J. Naiman, W.E. Riebsame, M.G. Turner, T.J. Valone, Ecological Principles and Guidelines for Managing the Use of Land, Ecological Applications 10 (2000) 639–670.
[32] S.a.I.J.E. Connick, Outcomes of collaborative water policy making: applying complexity thinking to evaluation, Journal of Environmental Planning and Management 46 (2003) 177–197.
[33] F. Danielsen, N. Burgess, A. Balmford, P. Donald, J. Jones, P. Alviola, D. Balete, T. Blomley, J. Brashares, B. Child, M. Enghoff, J. Fjelds, S. Holt, H. Hubertz, A. Jensen, P. Jensen, J. Massao, M. Mendoza, Y. Ngaga, M. Poulsen, R. Rueda, M. Sam, T. Skielboe, G. Stuart-Hill, E. Topp-jorgensen, D. Yonten, Local participation in natural resource monitoring: a characterization of approaches, Conservation Biology 23 (2009) 31–42.
[34] G. Cundill, Monitoring social learning processes in adaptive comanagement: three case studies from South Africa, Ecology and Society 15 (2010) 28.
[35] R. Bull, J. Petts, J. Evans, Social learning from public engagement: dreaming the impossible?, Journal of Environmental Planning and Management 51 (2008) 701–716.
[36] C. Pahl-Wostl, D. Tabara, R. Bouwen, M. Craps, A. Dewulf, E. Mostert, D. Ridder, T. Taillieu, The importance of social learning and culture for sustainable water management, Ecological Economics, 64 (2008) 484–495.
[37] G.T. Raadgever, E. Mostert, N.C. van de Giesen, Learning from collaborative research in water management practice, Water Resources Management 26 (2012) 3251–3266.
[38] I.S. Mayer, C.E. van Daalen, P.W. Bots, G. Perspectives on policy analyses: A framework for understanding and design, International Journal of Technology, Policy and Management 4 (2004) 169–191.
[39] B. Daniel, R.A. Schwier, G. McCalla, Social Capital in Virtual Learning Communities and Distributed Communities of Practice, Canadian Journal of Learning and Technology 29 (2003).
[40] H.G.K. Hummel, J. van Houcke, R.J. Nadolski, T. van der Hiele, H. Kurvers, A. Löhr, Scripted col*laboration in serious gaming for complex learning: Effects of multiple perspectives when acquiring water management skills, British Journal of Educational Technology 42 (2011) 1029–1041.
[41] R. Dyball, V. Brown, M. Keen, Towards sustainability: five strands of social learning, in: A.E.J. Wals (Ed.), Social learning towards a sustainable world; principles, perspectives, and praxis, Wageningen Academic Publishers, The Netherlands, 2007, pp. 181–195.
[42] C. Pahl-Wostl, The importance of social learning in restoring the multifunctionality of rivers and floodplains, Ecology and Society 11 (2006) 10.
[43] M.S. Reed, E.D.G. Fraser, A.J. Dougill, An adaptive learning process for developing and applying sustainability indicators with local communities, Ecological Economics 59 (2006) 406–418.
[44] R. Ison, D. Watson, Illuminating the possibilities for social learning in the management of Scotland's water, Ecology and Society 12 (2007) 21.
[45] E. Mostert, C. Pahl-Wostl, Y. Rees, B. Searle, D. Tàbara, J. Tippett, Social learning in European river-basin management: barriers and fostering mechanisms from 10 river basins, Ecology and Society 12 (2007) 19.
[46] C. Prell, K. Hubacek, C.H. Quinn, M.S. Reed, 'Who's in the network?' When stakeholders influence data analysis, Systemic Practice and Action Research 21 (2008) 443–458.
[47] J. Newig, D. Günther, C. Pahl-Wostl, In the network, Learning in governance networks in the context of environmental management, Ecology and Society 15 (2010) r1.
[48] P. Alexander, D.L. Schallert, R.E. Reynolds, What Is Learning Anyway? A Topographical Perspective Considered, Educational Psychologist, Routledge (2009).
[49] J. Sol, P.J. Beers, A.E. Wals, J. Social learning in regional innovation networks: trust, commitment and reframing as emergent properties of interaction, Journal of Cleaner Production 49 (2012) 35–43.
[50] D.R. Connor, Managing at the speed of change: How resilient managers succeed and prosper where others fail, Villard Books, New York (1993).
[51] C. Pahl-Wostl, E. Mostert, D. Tàbara, The growing importance of social learning in water resources management and sustainability science, Ecology and Society 13 (2008) 24.
[52] L. Clarke, The essence of change, Prentice Hall International, UK, 1994.
[53] G.a.B.M. Devos, Openness to organizational change: the contribution of content, context, and process, Vlerick Leuven Gent Management School (2003).
[54] M.S.a.V.d.V.A.H. Poole, Handbook of organizational change and innovation, Oxford University Press, New York, 2004.
[55] E.a.B.R. Applebaum, The new American workplace, Cornell University Press, Ithaca, NY, 1993.
[56] K. Lewin, Frontiers in group dynamics, Human Relations 1 (1947) 5–41.
[57] L. Isabella, Evolving interpretations as a change unfolds: How managers construe key organizational events, Academy of Management Journal 33 (1990) 7–41.
[58] T.J. Galpin, The human side of change, Jossey-Bass Inc (1996).
[59] A. Armenakis, H. Field, S. Harris, Making change permanent: A model for institutionalizing change interventions, in: a.W.WR. Passmore (Ed.), Research in organizational change and development, JAI Press, Stanford CT, 1999.
[60] A.a.B.A.G. Armenakis, Organizational change: A review of theory and research in the 1990s, Journal of Management 25 (1999) 293–315.
[61] C.B.F.a.G.P. Kuijpers, Perspectieven voor integral waterbeheer: een bestuurskundige analyse ten behoeve van de uitwerking van integral waterbeheer, SDU Uitgeverij, 's-Gravenhage, The Netherlands (1990).
[62] E. Mostert, Integrated Water Resources Management in the Netherlands: how concepts function, Universities Council on Water Resources, Journal of Contemporary Water Research & Education 135 (2006) 19–26.
[63] Beer, M.a.N., N., Breaking the code of change, Harvard Business School Press, Boston, MA, 2000.
[64] Self, D.R., Armenakis, A.A. and Schaninger, W.S. Jr. Employee reactions to organizational change content, process and context: A simultaneous analysis, Unpublished paper, 2001.
[65] P. Watzlawick, The Language of Change, Basic Books, New York, 1978.
[66] D.a.F. Miller, P.H. Organizations: A Quantum View, Prentice-Hall, Englewood Cliffs, NJ, 1984.
[67] C.R.a.G.R. Hinings, The Dynamics of Strategic Change, Blackwell, Oxford, 1988.
[68] T. Becher, Academic Tribes and Territories: intellectual enquiry and the culture of disciplines, SRHE and Open University Press, Buckingham, 1989.
[69] R. Williams, R. Slack, J. Stewart, Social learning, multimedia final report Edinburgh (2000).
[70] M. Oliver, What's the purpose of theory in Learning Technology? Working paper, Higher Education Research and Development Unit, University College, London, 2001.
[71] R.T.a.S.R.I. Mowday, Organizational behavior: Linking individuals and groups to organizational contexts, Annual Review of Psychology 44 (1993) 195–229.
[72] H.J. Walker, A.A. Armenakis, J.B. Bernerth, Factors influencing organizational change efforts: An integrative investigation of change content, context, process and individual differences, Journal of Organizational Change Management 20 (2007) 761–773.
[73] F. Damanpour, Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators, Academy of Management Journal 34 (1991) 555–590.
[74] L.T. Eby, D.M. Adams, J.E.A. Russell, S.H. Gaby, Perceptions of organizational readiness for change: Factor related to employees' reactions to the implementation of team-based selling, Human Relations 53 (2000) 419–442.
[75] B. Schneider, A.P. Brief, R.A. Guzzo, Creating a climate and culture for sustainable organizational change, Organizational Dynamics 24 (1996) 7–19.
[76] A. Armenakis, S. Harris, K. Mossholder, Creating readiness for organizational change, Human Relations 46 (1993) 681–703.
[77] J. Kotter, Leading change: Why transformation efforts fail, Harvard Business Review 73 (1995) 59–67.
[78] J.P.a.S.L.A. Kotter, Choosing strategies for change, Harvard Business Review 57 (1979) 106–112.
[79] C.R.a.B.J.T. Wanberg, Predictors and outcomes of openness to changes in a reorganizing workplace, Journal of, Applied Psychology 85 (2000) 132–142.
[80] J. Budner, Tolerance of ambiguity as a personality variable, Journal of Personality 30 (1962) 29–40.
[81] J.B. Rotter, Generalized expectancies for internal versus external control of reinforcement, Psychological Monographs 80 (1966).
[82] T.A. Judge, C.J. Thoresen, V. Pucik, T.M. Welbourne, Managerial coping with organizational change: A dispositional perspective, Journal of, Applied Psychology 84 (1999) 107–122.
[83] L.a.B.F. Carlsson, Co-management: concepts and methodological implications, Journal of Environmental Management 75 (2005) 65–76.
[84] D. Armitage, F. Berkes, A. Dale, E. Kocho-Schellenberg, E. Patton, Co-management and the co-production of knowledge: learning to adapt in Canada's Arctic, Global Environmental Change 21 (2011) 995–1004.
[85] M. Knowles, E. Holton, R. Swanson, The adult learner: The definitive classic in adult education and human resource development, Gulf Publishing Co., Houston, TX, 1998.
[86] M. Keen, S. Mahanty, Learning in sustainable natural resource management: challenges and opportunities in the Pacific, Society and Natural Resources 19 (2006) 497–513.
[87] M.E. Fernandez-Gimenez, H.L. Ballard, V.E. Sturtevant, Adaptive management and social learning in collaborative and community-based monitoring: a study of five community-based forestry organizations in the western USA, Ecology and Society 13 (2008) 4.
[88] R. Bouwen, T. Taillieu, Multi-party col*laboration as social learning for interdependence: developing relational knowing for sustainable natural resource management, Journal of Community and Applied Social Psychology 14 (2004) 137–153.
[89] P. Tosey, M. Visser, M.N.K. Saunders, The origins and conceptualizations of 'triple-loop' learning: a critical review, Management Learning 43 (2012) 291.
[90] D. Biggs, N. Abel, A.T. Knight, A. Leitch, A. Langston, N.C. Ban, The implementation crisis in conservation planning: could 'mental models' help? Conservation Letters 4 (2011) 169–183.
[91] C. Folke, F.S. Chapin III, P. Olsson, Transformations in social-ecological systems, in: F.S.I. Chapin, G.P. kofinas, C. Folke (Eds.), Principles of Ecosystem

Stewardship: Resilience-Based Natural Resource Management in a Changing World, Springer, New York, 2009.
[92] R.a.R.N. Flood, Diversity Management: Triple Loop Learning, Wiley, Chichester, 1996.
[93] D. Huitema, C. Cornelisse, B. Ottow, Is the jury still out? Towards greater insight in policy learning in participatory decision processes. The case of Dutch citizens' juries on water management in the Rhine basin, Ecology and Society 15 (2010) 16.
[94] M.a.S.K. Alvesson, Reflective methodology: new vistas for qualitative research, Sage, London (2000).
[95] D. Pedynowski, Prospects for Ecosystem Management in the Crown of the Continent Ecosystem, Canada-United States: Survey and Recommendations, Conservation Biology 17 (2003) 1261–1269.
[96] C.a.S.D. Argyris, Organizational learning: A theory of action perspective, Addison Wesley, Reading, Mass (1978).
[97] A.a.M.M. Groot, Demystifying facilitation in participatory interventions, Gatekeeper Series, Department of Communication and Innovation Studies, Wageningen Agriculture University, Wageningen, The Netherlands, 1999.
[98] F. Berkes, Evolution of co-management: Role of knowledge generation, bridging organizations and social learning, Journal of Environmental Management 90 (2009) 1692–1702.
[99] A.S. Cheng, C. Danks, S.R. Allred, The role of social and policy learning in changing forest governance: An examination of community-based forestry initiatives in the US, Forest Policy and Economics 13 (2011) 89–96.
[100] A. Wals, T. van der Leij, Introduction, in: A.E.J. Wals (Ed.), Social learning: towards a sustainable world, Wageningen Academic Publishers, Wageningen The Netherlands, 2007, pp. 17–32.
[101] C. Barnaud, A. Van Paassen, Equity, power games and legitimacy: dilemmas of participatory learning processes. in Proceedings of the 9th European International Farming Systems Association (IFSA) Symposium, University of Natural Resources and Applied Life Sciences, Vienna Austria (2010).
[102] D. Wildemeersch, Social learning revisited: lessons learned from north and south, in: A.E.J. Wals (Ed.), Social learning: towards a sustainable world, Wageningen Academic Publishers, Wageningen, The Netherlands, 2007.
[103] M. Hildén, The evolution of climate policies, the role of learning and evaluations, Journal of Cleaner Production 19 (2011) 1798–1811.
[104] F. Avelino, J. Rotmans, A dynamic conceptualization of power for sustainability research, Journal of Cleaner Production 19 (2011) 796–804.
[105] W. Medema, Integrated water resources management and adaptive management: shaping science and practice (PhD thesis), School of Applied Science, Cranfield University, Cranfield UK, 2008.
[106] P. Huntjens, C. Pahl-Wostl, R. Schulze, N. Kranz, J. Camkin, L. Lebel, Chapter 9: Institutional design principles for climate change adaptation, in: P. Huntjens (Ed.), Water Management and Water Governance in a Changing Climate – Experiences and insights on climate change adaptation in Europe, Asia, Africa and Asia (PhD Thesis), Eburon, Academic Publishers, University of Osnabrueck, Institute for Environmental Systems Research, Germany, 2011.
[107] P. Huntjens, C. Pahl-Wostl, Z. Flachner, S. Neto, R. Koskova, M. Schlueter, I. NabideKiti, C. Dickens, Adaptive Water Management and Policy Learning in a Changing Climate. A formal comparative analysis of eight water management regimes in Europe, Asia, and Africa, Policy Governance 21 (2011) 145–163.
[108] A.a.H.T. Johannessen, Social learning towards a more adaptive paradigm? Reducing flood risk in Kristianstad municipality, Sweden, Global Environmental Change 23 (2013) 372–381.
[109] L. Ackerman, Development, transition or transformation: The question of change in organizations, in: D. Van Eynde, J. Hoy, D. Van Eynde (Eds.), Organisation Development Classics, Jossey Bass, San Francisco, 1997.
[110] K.E. Weick, Small wins: Redefining the scale of social problems, American Psychologist 19 (1984) 40–49.
[111] B.A. Lankford, D.J. Merrey, J. Cour, N. Hepworth, From integrated to expedient: An adaptive framework for river basin management in developing countries, International Water Management Institute, Colombo, Sri Lanka (2007).
[112] S.L. Somach, Closing the Policy-Practice Gap in Water Resources Planning, Water Resources Update (1993) 19–22.
[113] P.a.M.M.W. Berman, Federal Programs Supporting Educational Change, Rand, Santa Monica (1978).
[114] J.L.a.W.A.B. Pressman, Implementation: How great expectations in Washington are dashed in Oakland: or, why it's amazing that federal programs work at all, this being a saga of the Economic Development Administration as told by two sympathetic observers who seek to build morals on a foundation of ruined hopes, University of California Press, Berkeley (1984).
[115] K.G.a.K.M.E. Tidball, Greening in the Red Zone: disaster resilience and community greening, Springer (2014).
[116] L. Lebel, J.M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. Hughes, J. Wilson, Governance and the capacity to manage resilience in regional social–ecological systems, Ecology and Society 11 (2006) 19.
[117] M.T. Imperial, Institutional analysis and ecosystem-based management: the institutional analysis and development framework, Environ. Manag. 24 (1999) 449–465.
[118] P. Huntjens, C. Pahl-Wostl, J. Grin, Climate change adaptation in European river basins, Regional Environ. Change 10 (2010) 263–284.
[119] A.E.J. Wals, N. van der Hoeven, H. Blanken, The acoustics of social learning: Designing learning processes that contribute to a more sustainable world, Wageningen Academic Publishers, The Netherlands (2009).
[120] L. Gunderson, Resilience, Flexibility and Adaptive Management – Antidotes for Spurious Certitude?, Conservation Ecology 3 (1999) 7.
[121] P. Olsson, L.H. Gunderson, S.R. Carpenter, P. Ryan, L. Lebel, C. Folke, C.S. Holling, Shooting the rapids: navigating transitions to adaptive governance of social–ecological systems, Ecology and Society 11 (2006).
[122] S. Nooteboom, Adaptive Networks - The Governance for Sustainable Development, Eburon Academic Publishers, Delft, The Netherlands (2006).
[123] Ostrom, E., Scales, polycentricity, and incentives: Designing complexity to govern complexity, in: L.D.a.M. Guruswamy, J. A. (Ed.) Protection of global biodiversity: Converging strategies, Duke University Press, Durham, NC, 1998.
[124] M. McGinnis, Polycentric Games and Institutions: Readings from the Workshop in Political Theory and Policy Analysis, University of Michigan Press, Ann Arbor (2000).
[125] J.D.a.P.-W.C. Tàbara, Sustainability learning in natural resource use and management, Ecology and Society 12 (2007) 3.
[126] W.N. Adger, N.W. Arnell, E. Tompkins, Successful adaptation to climate change across scales, Glob. Environ. Change 15 (2005) 77–86.
[127] M.T. Kok, H.C. de Coninck, Widening the scope of policies to address climate change: directions for mainstreaming, Environ. Sci. Policy 10 (2007) 587–599.
[128] L. Bohunovsky, J. Jäger, I. Omann, Participatory scenario development for integrated sustainability assessment, Regional Environmental Change (Online first) (2010).
[129] M.L.M. Graymore, N.G. Sipe, R.E. Rickson, Sustaining human carrying capacity, A tool for regional sustainability assessment, Ecological Economics 69 (2010) 459–468.
[130] Pekkarinen, S.a.H., V. Building regional innovation networks: the definition of an age business core process in a regional innovation system, Regional Studies, 40 401-413.
[131] Gaventa, J., Cornwall, A, Power and knowledge, in: P. Reason, Bradbury, H. (Ed.) The SAGE Handbook of Action Research, Sage, London, UK, 2001, pp. 172-189.
[132] Z. Fadeeva, Promise of sustainability col*laboration - potential fulfilled? Journal of Cleaner Production 13 (2005) 165–174.
[133] J.a.R.N. Jiggins, Adaptive management: potential and limitations for ecological governance of forests in a context of normative pluriformity, in Oglethorpe, in: J.A.E. Oglethorpe (Ed.), Adaptive management: from theory to practice, IUCN, Gland, Switzerland, 2002, pp. 93–104.
[134] D.W. Cash, W. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard, O. Young, Scale and Cross-Scale Dynamics: Governance and Information in a Multilevel World, Ecology and Society 11 (2006) 8.
[135] D. Kelly, Community participation in rangeland management, Rural Industry Research and Development Corporation, Canberra (2001).
[136] D.W. Cash, W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D. Guston, J. Jager, R. Mitchell, Knowledge systems for sustainable development, Proceedings of the National Academy of Sciences of the United States of America 100 (2003) 8086–8091.
[137] F. Geels, E.B.K. Green, General introduction: systems innovation and transitions to sustainability, in: B. Elzen, F. Geels, K. Green (Eds.), Systems innovation and the transition to sustainability: Theory, evidence and policy, Edward Elgar, Cheltenham, 2004, pp. 1–16.
[138] T.a.B.R. Meashham, Combining people, place and learning, in: M. Keen, V.A. Brown, R. Dyball (Eds.), Social learning in environmental management: towards a sustainable future, Earthscan, London, 2005.
[139] D. Bohm, On dialogue, Routledge, London, 1996.
[140] B.M.a.R.J. Staw, Stability in the midst of change; a dispositional approach to job attitudes, Journal of, Applied Psychology 70 (1985) 469–480.
[141] B. Schneider, The people make the place, Personnel Psychology 40 (1987) 437–453.
[142] Bray, D.W., Personnel-centered organizational diagnosis, in: A.e.a. Howard (Ed.) Diagnosis for Organizational Change, Guilford Press, New York, 1994, pp. 152-171.
[143] Schein, E.H., Organizational psychology, Prentice Hall, Englewood Cliffs, NJ, 1980.
[144] J. Evans, Bias in Human Reasoning: Causes and Consequences, Psychology Press, UK, 1990.
[145] E.H. Schein, The Corporate Culture Survival Guide: Sense and Nonsense about Cultural Change, Jossey-Bass Inc., San Francisco, 1999.
[146] R.a.C.P.T. McCrae, Personality, coping, and coping effectiveness in an adult sample, Journal of Personality 54 (1986) 385–405.
[147] M. Snyder, The self-monitoring of expressive behavior, Journal of Personality and Social Psychology 30 (1974) 526–537.
[148] G. Hofstede, The business of international business is culture, International Business Review 3 (1994) 1–14.
[149] J. Webster, Culture's influence: towards understanding stakeholder interaction in rural water, sanitation and hygiene promotion projects, Institute of Water and Environment, Cranfield University, Cranfield, UK (2006).
[150] S. Gasteyer, C.B. Flora, Measuring ppm with tennis shoes: science and locally meaningful indicators of environmental quality, Society and Natural Resources 13 (2000) 589–597.
[151] J. Kusel, L. Williams, C. Danks, J. Perttu, L. Wills, D. Keith, L.P. Group, A report on all-party monitoring and lessons learned from the pilot projects, Forest Community Research and The Pacific West National Community Forestry Center, Taylorsville, California USA (2000).
[152] M.E. Fernandez-Gimenez, G. Ruyle, S. Jorstad McClaran, An evaluation of Arizona Cooperative Extension's rangeland monitoring program, Rangeland Ecology and Management 58 (2005) 89–98.
[153] Schön, D.A., A study of field experience, Unpublished memorandum, Massachusetts Institute of Technology, 1973.

[154] C.L.a.F.-G.M.E. Wagner, Does community-based collaborative resource management increase social capital? Society and Natural Resources 13 (2008) 4.
[155] S.C.a.R.W. Babu, Monitoring natural resources for policy interventions: a conceptual framework, issues, and challenges, Land Use Policy 12 (2000), b1-11.
[156] Grant, R.M., Shifts in the world economy: The drivers of knowledge management, in: C.a.C. Despres, D. (Ed.) Knowledge horizons: The present and the promise of knowledge management, ButterworthHeinemann, 2000, pp. 27-54.
[157] D.a.S.P. Snowden, The landscape of management: Creating the context for understanding social complexity E:CO Special Double Issue 6 (2004) 140–148.
[158] P.a.V.D.E. Bots, Functional design of games to support natural resource management policy development, Simulation Gaming OnlineFirst (2007).
[159] N.M. Consortium, Spring 2007 survey: Educators in second life (2007).
[160] A.M.a.H.M. Kaplan, The challenges and opportunities of social media, Business Horizons 53 (2010) 59–68.
[161] S.a.P.F. Mysirlaki, Online Games for the Next Generation of Worke, I.J. Advanced Corporate Learning 3 (2010) 21–25.
[162] F. Paraskeva, S. Mysirlaki, V.N. Vasileiou, Developing Self-Regulation Skills in Virtual Worlds: An Educational Scenario Applied in Second Life, IJOPCD 2 (2012) 25–43.
[163] Oblinger, D.a.O., J., Educating the Net Generation, in: D.a.O. Oblinger, J. (Ed.), EDUCAUSE, 2005.
[164] W. Gibson, A. Hall, P. Callery, Topicality and the structure of interactive talk in face-to-face seminar discussions: implications for for research in distributed learning media, British Educational Research Journal 32 (2006) 77–94.
[165] M. Castells, Communication power, Oxford University Press Inc., New York, 2011.
[166] M. Castells, Communication Power, Oxford University Press, Oxford, New York, 2009.
[167] Giunchiglia, F.a.R., D., The Social Computer: combining machine and human computation Tech. Rep. 10-036, DISI, University of Trent, 2010.
[168] C. Shirky, The political power of social media: technology, the public sphere, and political change, Foreign Affairs, Council on Foreign Relations (2011).
[169] M. Hall, Tourism governance: Critical perspectives on governance and sustainability, Journal of Sustainable Tourism 19 (2011) 649–671.
[170] C. Dede, Planning for neomillennial learning styles: Shifts in students' learning style will prompt a shift to active construction of knowledge through mediated immersion, Educause Quarterly 28 (2005) 7–12.
[171] G. Siemens, Connectivism: Learning as Network Creation, elearnspace (2008).
[172] S. Bronack, R. Riedl, J. Tashner, Learning in the zone: A social constructivist framework for distance education in a 3-dimensional virtual world, Interactive Learning Environments 14 (2006) 219–232.
[173] B.a.L.M.J.W. Dalgarno, What are the learning affordances of 3-D virtual environments?, British Journal of Educational Technology 41 (2010) 10–32.
[174] M.D. Dickey, The pragmatics of virtual worlds for K-12 educators: Investigating the affordances and constraints of Active Worlds and Second Life with K-12 in-service teachers, Educational Technology Research and Development 59 (2011) 1–20.
[175] A.M. Devlin, V. Lally, M. Sclater, K. Parussel, Inter-Life: a novel, three-dimensional, virtual learning environment for life transition skills learning, Interactive Learning Environments (2013).
[176] A.M. Devlin, V. Lally, M. Sclater, K. Parussel, The development of life transition skills in Inter-Life: A novel, 3-dimensional Virtual Learning Environment. in CSCL 2011 conference proceedings University of Hong Kong, China: International Society of the Learning Sciences (2011).
[177] K.a.R.S. Hibbert, Virtual communities of practice, in: J. Weiss, J. Nolan, J. Hunsinger, P. Trofonas (Eds.), The international handbook of virtual learning environments, Kluwer Adademic Publishers, Dordrecht, The Netherlands, 2006.
[178] A.M. Devlin, V. Lally, M. Sclater, K. Parussel, Inter-life: A novel, three-dimensional, virtual learning environment for life transition skills learning, Interactive Learning Environments, iFirst Article (2013).
[179] M.M. Hansen, Versatile, immersive, creative and dynamic virtual 3-D healthcare learning environments: a review of the literature, J. Med. Internet Res. 10 (2008).
[180] S. De Freitas, G. Rebolledo-Mendez, F. Liarokapis, G. Magoulas, A. Poulovassilis, Learning as immersive experiences: Using the four dimensional framework for designing and evaluating immersive learning experiences in a virtual world, British Journal of Educational Technology 41 (2010) 69–85.
[181] A.M. Devlin, V. Lally, B. Canavan, J. Magill, The role of the "Inter-Life" virtual world as a creative technology to support student transition into higher education, Creative Education 4 (2013) 191–201.
[182] M.D. Dickey, Three dimensional virtual worlds and distance learning: Two case studies of active worlds as a medium for distance education, British Journal of Educational Technology 36 (2005) 439–451.
[183] C. Dede, Immersive interfaces for engagement and learning, Science 323 (2009) 66–68.
[184] A.M. Devlin, B. Canavan, J. Magill, V. Lally, Evaluation of the novel Inter-Life virtual world as an innovative technology to support transition to University, European Conference on Educational Research (ECER), University of Cadiz (2012).
[185] L.R. Ayers, S.C. Beyea, M. godfrey, D.C. Harper, E.C. Nelson, P.B. Batalden, Quality improvement learning collaboratives, Quality Management in Health Care 14 (2005) 234–247.
[186] B.L.a.J.T. Fredrickson, Positive emotions trigger upward spirals toward emotional wellbeing, Psychological Science 13 (2002) 172–175.
[187] C. Chew, G.J. Lloyd, E. Knudsen, An interactive capacity building experience – an approach with serious games, Serious Games and Social Connect Conference, Singapore (2013).
[188] A. van Bilsen, G. Bekebrede, I. Mayer, Understanding Complex Adaptive Systems by Playing Games, Informatics in Education 9 (2010) 1–18.
[189] I. Mayer, The gaming of policy and the politics of gaming: A review, Simulation Gaming 40 (2009) 825–861.
[190] A.Y. Hoekstra, Computer-supported games and role plays in teaching water management, Hydrology and Earth System Sciences 16 (2012) 2985–2994.
[191] G. Learmonth, D. Smith, W. Sherman, M. White, J. Plank, A practical approach to the complex problem of environmental sustainability: The UVa Bay game®, The Innovation Journal: The Public Sector Innovation Journal 16 (2011), Article 4.
[192] V. Souchère, L. Millair, J. Echeverria, F. Bousquet, C. Le Page, M. Etienne, Co-constructing with stakeholders a role-playing game to initiate collective management of erosive runoff risks at the watershed scale, Environmental Modelling & Software 25 (2010) 1359–1370.
[193] I. Mayer, G. Bekebrede, C. Harteveld, H. Warmelink, Q. Zhou, T. van Ruijven, J. Lo, R. Kortmann, I. Wenzler, The research and evaluation of serious games: Toward a comprehensive methodology, British Journal of Educational Technology (2013).
[194] H. Kim, R.D. Caytiles, T. Kim, Design of an effective WSN-based interactive u-learning model, International Journal of Distributed Sensor Networks (2012) 12.