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Exploring the Potential Impact of Serious Games on Social Learning and Stakeholder Collaborations for Transboundary Watershed Management of the St. Lawrence River Basin

Wietske Medema [1,*], Alison Furber [1], Jan Adamowski [1], Qiqi Zhou [2] and Igor Mayer [3]

[1] Department of Bioresource Engineering, McGill University, 21 111 Lakeshore, Ste Anne de Bellevue, QC H9X3V9, Canada; alison.furber@mail.mcgill.ca (A.F.); jan.adamowski@mcgill.ca (J.A.)
[2] TIAS School for Business and Society, Kromme Nieuwegracht 39, Utrecht 3512 HD, The Netherlands; qiqi.zhou@tias.edu
[3] Academy for Digital Entertainment, NHTV Breda University of Applied Sciences, Monseigneur Hopmansstraat 1, Breda 4817 JT, The Netherlands; i.s.mayer@hotmail.com
* Correspondence: wietske.medema@mcgill.ca; Tel.: +1-514-398-7786

Abstract: The meaningful participation of stakeholders in decision-making is now widely recognized as a crucial element of effective water resource management, particularly with regards to adapting to climate and environmental change. Social learning is increasingly being cited as an important component of engagement if meaningful participation is to be achieved. The exact definition of social learning is still a matter under debate, but is taken to be a process in which individuals experience a change in understanding that is brought about by social interaction. Social learning has been identified as particularly important in transboundary contexts, where it is necessary to reframe problems from a local to a basin-wide perspective. In this study, social learning is explored in the context of transboundary water resource management in the St. Lawrence River Basin. The overarching goal of this paper is to explore the potential role of serious games to improve social learning in the St. Lawrence River. To achieve this end, a two-pronged approach is followed: (1) Assessing whether social learning is currently occurring and identifying what the barriers to social learning are through interviews with the region's water resource managers; (2) Undertaking a literature review to understand the mechanisms through which serious games enhance social learning to understand which barriers serious games can break down. Interview questions were designed to explore the relevance of social learning in the St. Lawrence River basin context, and to identify the practices currently employed that impact on social learning. While examples of social learning that is occurring have been identified, preliminary results suggest that these examples are exceptions rather than the rule, and that on the whole, social learning is not occurring to its full potential. The literature review of serious games offers an assessment of such collaborative mechanisms in terms of design principles, modes of play, and their potential impact on social learning for transboundary watershed management. Serious game simulations provide new opportunities for multidirectional collaborative processes by bringing diverse stakeholders to the table, providing more equal access to a virtual negotiation or learning space to develop and share knowledge, integrating different knowledge domains, and providing opportunities to test and analyze the outcomes of novel management solutions. This paper concludes with a discussion of how serious games can address specific barriers and weaknesses to social learning in the transboundary watershed context of the St. Lawrence River Basin.

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1. Introduction

A significant portion of the world's watersheds straddle jurisdictional boundaries where political and hydrological boundaries often do not correspond [1]. Particular challenges relating to resource management in such transboundary contexts include differing legal and regulatory frameworks, languages, economic conditions, political history and antecedents with public participation, and stakeholder organizations [2]. When looking at the current state of Canada's governing structure, as an example, it shows a division and fragmentation between jurisdictions of federal, provincial, territorial and the First Nations governments [3]. In Canada, provincial governments have jurisdiction over water as a resource, while the federal government mainly has jurisdictional authority over water issues and conflicts with the US [4]. This fragmentation has resulted in overlapping resource management policies that do not work together while creating transboundary issues, as well as a decreased water quality of Canadian watersheds [5]. In addition to this challenge of fragmentation, many environmental government authorities are experiencing various budgetary reductions, which is devolving the national- and provincial-level capacity to address water resource issues [4].

To ensure that the water governance system in Canada can cope given the challenges it is facing, including increasing pressures on water resources from highly urbanized and agricultural developments, the contamination of both surface and groundwater bodies, and climate change, a transition from current management regimes to a coordinated sharing of power and responsibilities, and partnerships between public, private and civil society stakeholders is necessary [6]. Overcoming transboundary water governance differences requires problems to be reframed from a local to a basin-wide perspective [7–9]. It also requires more inclusive forms of watershed management that seeks to increase the participation and engagement of a more diverse group of stakeholders [10]. Strong platforms for collaboration and interaction that enhance communications, information sharing, negotiations and knowledge co-creation, are mechanisms essential to facilitating positive relationships and dynamics between diverse stakeholders [7].

Social learning is becoming a "normative goal" for water governance and a key for addressing transboundary water issues [7–9]. According to Reed *et al.* [11], social learning refers to learning achieved by the social group as a whole, and involves a process in which individuals experience a change in understanding that has a social dimension in that it is brought about by social interaction and is linked to wider communities of practice. Mostert *et al.* [8] identify a number of components of collaboration that follow a social learning approach. In particular, they highlight the importance of recognizing mutual dependence and the role that trust plays. They emphasize the need to interact, share problem perceptions and develop alternative solutions. Lastly, they talk of the need for stakeholders to engage in collaborative decision making processes and jointly implement agreed actions. Mostert *et al.* [8] takes a broader perspective on social learning than Reed *et al.* [11] by recognizing mutual dependence and trust as prerequisites, while conceptualizing stakeholder interactions, the sharing of problem perceptions, and the development of alternative solutions as actions indicative of underlying social learning processes. Collaborative decision-making processes and the joint implementation of agreed actions are both prerequisites to, and potential desirable outputs of, social learning processes [12,13]. The value of this broader perspective is that, while assessing the extent to which internal change in understanding has taken place is complex and difficult to measure, external factors such as the extent of interaction and the degree to which problem perspectives are shared offer more tangible substitutes.

The goal of this paper is to assess the effectiveness of social learning practices for transboundary management within the St. Lawrence River watershed in North America and identify opportunities

for enhancing social learning. This watershed faces a particularly complex set of transboundary challenges: jurisdiction is shared between two countries, several Canadian provinces, and numerous local governments [3], which leads to the involvement of a diverse range of stakeholders (e.g., the general public, industry, farmers, small business owners, civil servants and politicians of various levels). Such challenges require novel tools and methods to encourage dialogue, facilitate learning and enable systemic institutional change, so that decisions can be made from a position of shared knowledge and understanding. Serious games offer innovative solutions for enhancing learning and collaborations to overcome governance challenges [8,12,13]. These types of games combine computer simulation with role-play as an integrated method for complex policy making while triggering discussion and learning among stakeholders [14]. Serious games involve simulations of real-world events or processes designed for the purpose of solving contemporary societal challenges, and these games are therefore designed for a purpose beyond entertainment. Serious games have been successfully used in other sectors (e.g., education, military and health) and are now beginning to be explored in the water sector [15,16].

The following section will provide a literature review of the conditions and factors that are required for the facilitation of social learning and multi-stakeholder collaborations in a transboundary watershed context. Additionally, a review is offered through which serious games are assessed in terms of design principles, modes of play, and their potential impact on social learning for transboundary watershed governance. Following this, the methodology is presented, to achieve the research goal, in-depth interviews have been conducted with 10 of the region's key water resources managers. This paper concludes with a discussion of the study results and findings.

2. Social Learning and Serious Gaming

2.1. Social Learning for Transboundary Watershed Governance

A management paradigm called Adaptive Management was proposed in the 1970s to guide the management of resources and bring learning to the fore as a central tenant of effective management and to encourage resource managers to take steps to learn about the processes which govern a certain system [17–20]. With the need for more participatory forms of water resources management over the past decade, the Adaptive Management approach has been broadened with learning now commonly taken to be an essential social process [17]. As an example, Stringer *et al.* [21] describe Adaptive Management as a paradigm that "treats knowledge about ecosystems as both uncertain and pluralistic while recognizing that in order to create more sustainable management strategies, stakeholders must forge new relationships to enhance multi-directional information flows, learn from each other, and together develop flexible ways of managing their environment".

Multi-faceted issues associated with transboundary watershed governance are problematic due to diverse management regimes and potential asymmetries in resources, political structures, government agencies and institutions [22]. In order to achieve more adaptive and integrated forms of resource management, it is important to acknowledge that boundaries are always present and that collaborations across such boundaries are essential [8,23–25]. Such boundaries not only involve physical boundaries (e.g., between surface and groundwater, water quantity and quality, freshwater and coastal waters, water resources and land resources, different geographical scales) or jurisdictional boundaries (e.g., between different countries, government levels, policy sectors), but also boundaries of a social (between different social and economic groups, and between these groups and government) as well as a cognitive nature (between different disciplines and expertise). Social learning is recognized as a mechanism to support the facilitation of collaboration and interaction between stakeholders across these boundaries [8,12,13]. While there is not one stakeholder that carries all legal competencies, funds, information and other required resources to manage water issues, it is important for these parties to pool resources and "learn together to manage together" [8].

Such social learning processes take place in both a social context (*i.e.*, the governance system, economy and culture) as well as a natural context (*i.e.*, the hydrological and geographical conditions) that together play a crucial role in determining who the key stakeholders are and what they see as the key management issues. Social learning implies that these different stakeholders learn to resolve these issues through social interactions and relationships in order to come to a shared understanding of the problems at stake and the system to be managed, as well as to agree on a solution while ensuring that this solution is implemented [8]. The term "stakeholders" for this study encompasses parties who hold power and knowledge to influence the outcome of resource management decisions, and those affected by the actions taken [26]. Stakeholder participation is considered a critical component for transboundary watershed governance and the facilitation of social learning, and for this study it is conceptualized for this study according to typologies that distinguish between the degree to which stakeholders are engaged [27]. In this light, Arnstein [28] recognizes that stakeholder participation efforts vary in the amount of control given to stakeholders and identified different "rungs" on a "ladder of stakeholder participation" characterized by increasing stakeholder power [28]. This author developed different typologies based on these "rungs" to distinguish between the degree of stakeholder engagement. More recently, Chase *et al.* [29] outlined a similar range of approaches to stakeholder participation for the context of natural resources management, and argued that these approaches form a logical continuum over which the relative influence of citizens and agencies over management varies—from total agency control under the expert authority approach to broad power-sharing under co-management [29]. The degree of stakeholder engagement is conceptualized by these authors according to five typologies [30]:

1.   *Expert authority*—agencies retain full responsibility for decision-making and do not consider stakeholder input during decision-making;
2.   *Passive-receptive*—agencies consider stakeholder input, but do not actively seek it out;
3.   *Inquisitive*—agencies make systematic attempts to gather stakeholder input while retaining authority for deciding how to weigh this information;
4.   *Transactional*—agencies facilitate a process in which stakeholders work together to try to reach agreement on the best management decision, and;
5.   *Co-management*—agencies work with stakeholders in partnership and involve them throughout the management process.

Co-management has been emphasized by Raadgever *et al.* [31] as being crucial for effective transboundary watershed governance where strong stakeholder networks must be in place that foster stakeholder participation and collaboration. Edelenbos *et al.* [32] highlight how such stakeholder networks are subsequently key in facilitating: the generation, acquisition, and diffusion of different knowledge types; multi-directional dialogue and interaction; shared understanding and sense making; mobilization and allocation of key resources for effective governance; commitment to common rules; willingness to engage in collaborative processes; and mutual trust and conflict resolution. Muro and Jeffrey [33] also provide a summary of conditions for promoting social learning based on many studies exploring the relationship between stakeholder engagement processes and outcomes. These conditions, as well as those identified by a number of other scholars that have studied different categories and types of collaborative network conditions in the context of water governance [32–43], are synthesized for this study into four key categories: (1) *properties of stakeholders*: the characteristics of stakeholders who are participating in collaborative networks; (2) *properties of collaborative processes*: the way interactions, communication and collaboration are organized; (3) *properties of relationships*: the quality of the relationships between members of a network; and (4) *properties of knowledge*: the properties of knowledge and understanding that is developed and shared within and between networks.

In assessing the effectiveness of social learning processes, it is complex and difficult to assess the extent to which *internal* changes in stakeholder understanding, norms and values have taken place as a result of social learning processes. For this reason, this paper focuses primarily on

studying more tangible and *external* elements that effective social learning processes have in common. This study will look primarily at the characteristics of stakeholders participating in social learning processes (such as stakeholder preparedness to participate, and their available resources), the extent of stakeholder interactions and the way this engagement process is organized (such as stakeholders' recognition of their interdependence, and ongoing critical reflection), the quality of relationships between stakeholders and their attitudes towards one another (involving repeated interaction, mutual trust, respecting diversity, and the degree to which problem perspectives are shared). These factors are summarized in Table 1 below and form the foundation for the acquisition and analysis of research data for this study.

Table 1. Key elements of social learning processes.

Elements of Social Learning	References
Characteristics of stakeholders	
Stakeholder preparedness to participate	[35,37,39,44]
Available resources (e.g., facilities, organizational forms and competences)	[36,37,41]
Critical self-reflection on positions and goals	[8]
Stakeholder interactions and the way the engagement process is organized	
Involvement of crucial stakeholders	[32,34,37,39,44]
Including and respecting diverse interests, views and information	[8,32–34,36,37,42,43,45]
Development and assessment of potential solutions	[8]
Joint decision-making and implementation through open communication and interaction	[8,33,45]
Exchange of problem perspectives, knowledge and information	[8,33,36,37,46]
Ongoing reflection on positions, perspectives and goals	[8,33,34,36,47,48]
Quality of stakeholder relationships	
Development of strong network ties through prolonged and frequent interactions	[8,33,38,39,42,48,49]
Recognition of interdependence and shared goals	[8,34,42]
Mutual trust and commitment between stakeholders	[8,33,35,42]

2.2. Serious Game Play for Social Learning

Social learning may be viewed as an approach for analyzing and promoting stakeholder collaboration [8]. While social learning involves the crossing of boundaries and bridging of differences, it often requires some form of external facilitation that supports the social process and constructive interactions between stakeholders [8,12,13,50]. Mostert *et al.* [8] highlight that framing and re-framing processes are central to social learning, and emphasize the importance of re-framing from a common frame in transboundary watershed management of "sharing scarce water resources" to an alternative frame of "benefit sharing" that focuses on the benefits that may be derived from water resources, while turning transboundary watershed management into a win-win game [51,52]. Numerous methods to foster learning through collaborative and multi-stakeholder participation have been developed and implemented, from modeling and computer simulation to policy interventions such as panels, workshops and process management [14]. One promising category involves serious games that have the ability to encourage social learning. The concept of simultaneously addressing the techno-physical complexities of a system (*i.e.*, the underlying physical elements of the system) and the socio-political complexities (*i.e.*, the non-linear agencies of the stakeholder network) via an integrated simulation, or serious game, is very appealing [16,53,54].

Transboundary watershed governance involves a dynamic and interactive arena with a complex multi-stakeholder setting and often-conflicting interests that resembles a strategic and messy game [16]. These complex multi-stakeholder settings require methodologies and tools that are able to support managers in their ability to deal with the technical-physical as well as the social-political complexity

of transboundary watershed governance. It is essential to integrate these two types of complexities, and serious games offer a mechanism through which stakeholders become a more intrinsic part of a computer model, not just as digital agents but as actual game players with real stakes, tacit knowledge, emotions, intuitions and interests [14]. A number of authors [16,18,55–59] highlight that the learning (both individually as well as socially) that occurs through such participation in a game simulation may be transferred to the real world outside the game, while at the same time providing a low-risk and safe environment in which to creatively experiment. Serious games may therefore be seen as a form of intervention within a multi-stakeholder network setting that involves learning and changing of stakeholders' mental frames of transboundary water issues, while at the same time offering opportunities to learn about and change the social-political structure (*i.e.*, by building trust, forming coalitions, and power plays in which the stakeholder network is embedded) [14].

Stakeholder participation in serious game simulations may provide significant support in the formation of new or stronger coalitions and collaborative partnerships while addressing existing power plays and building trust with other stakeholders [14,60,61]. Serious game simulations are particularly well suited for knowledge co-creation for situations where the underlying systems are vast in scale, interconnected or complex [62], which is often the case when it comes to transboundary river watersheds. Knowledge co-creation is an important element to social learning, while the sustainable governance of water resources relies greatly on diverse and multi-faceted knowledge systems, through which knowledge is continuously updated to reflect current understanding and needs [32]. Serious game simulation events provide creative platforms that allow stakeholders to share and transfer knowledge, understandings and perspectives through face-to-face interactions and discussions [14]. Such events offer opportunities and space for stakeholder communication, knowledge diffusion processes and the systemization of knowledge [32]. Interactive multi-player game formats that facilitate step-wise, round-based interactions allow participants to develop a greater understanding of different perspectives while also providing a platform for interactions between upstream and downstream contexts of a river watershed [53,62,63]. Role play characteristics of serious games may support the development of empathy and trust between stakeholders, as they develop a much greater understanding of what is required for effective transboundary governance.

Overall, it can be argued that serious games hold advantages over more conventional collaborative methodologies and tools owing to their competitive and entertainment aspects, as well as their role-play-game characteristics and feedback mechanisms [61]. A number of authors [13–15,53,54,60–67] have discussed key characteristics of serious games that are in support of social learning and stakeholder collaborations, which have been summarized in Table 2. Serious games can provide immersive learning opportunities, although the argument can be made that generally engagement goals go beyond just the desire to learn, *i.e.*, what is the problem to be solved that would bring key stakeholders together and want to make them play serious games? In this light, it should be noted that learning cannot remain restricted to acquiring knowledge of specific content matter, but also has to deal with selecting and using this knowledge for certain problem situations in a specific context—in this case, that of transboundary watersheds. Hummel *et al.* [68] highlight that social learning is about the acquisition of competences such as information skills, media literacy, problem-solving, communication and collaboration, as well as critical reflection about complex problems [68]. These authors also emphasize that serious games as virtual learning environments with scripted collaborative interactions have the potential to increase the quality of learning output. Although solitary (single-user) games may not provide the stakeholder interactions and collaborative effects that are required for social learning, multiplayer and multi-role games can enable and provoke social learning and collaborative task activity [53,62,63,68].

In serious games, stakeholders can interact both virtually as well as in reality. Allowing stakeholders to play different roles, not only provides opportunities for interactive learning, but provides players with great opportunities to take conflicts or specific water issues as a starting point for learning while discovering multiple aspects and perspectives of a problem during the game-play [68].

Such conflicts when solving a water management problem can be exchanged, reflected upon and integrated through participation in serious games by both taking an ecological as well as a governance perspective of the case [69]. While social learning does not occur due to one-off engagement but repeat engagement, it is essential that serious game events offer mechanisms that become a part of and contribute to an ongoing process of stakeholder interactions (through, e.g., game design and development, facilitated interactions, game play, post-game discussion, *etc.*), and that provide a type and format of knowledge and information that players can directly use and apply in their day-to-day activities and institutions [14,60]. When serious games meet these requirements, they contribute to social learning through both the "cognitive enhancement" of participants (*i.e.*, the acquisition and integration of knowledge) and "moral development", focusing on the interactive, inter-personal dimension of appraisal [69,70].

Table 2. Characteristics of serious games in support of social learning.

Serious Game Characteristics	Supporting Support Social Learning and Multi-Stakeholder Collaborations	References
Challenging	Facilitating deeper learning by including underlying competitive forces that affect decision-making at a variety of levels, while challenging participants to do better and to compete with others, themselves or a system	[14,60,61,66,67]
Entertaining and engaging	The immersive and competitive aspects of serious games can engage and entertain stakeholders that normally do not interact while providing incentives and enhancing motivation for coordinated action	[13,54,60,65]
Experiential	Experiential learning as an intended design element takes place as a result of the game play participation and relies on rounds of actions, trial and error, and feedback	[14,15,60,61]
Experimental	Learning occurs in a step-wise exploratory manner with actors experimenting with successive rounds of innovation in order to continually assess and improve upon the existing situation	[14,53,60,71]
Providing feedback	Exploring cause-effect relationships through feedback loops between outcomes and subsequent decisions is essential for players to develop knowledge and a deeper understanding of the system they are embedded in, while also encouraging collective sense making and critical self-reflection	[14,53,60,66,67]
Immersive	By creating a platform that stimulates creativity and innovation by exhibiting some degree of immersion that involves the replication of certain real-world elements (*i.e.*, through stories, visuals, a 3D world and levelling) to create a feeling of excitement and flow	[14,60,66,67,72]
Dynamic and interactive	Exhibiting various degrees of interaction with other players, with computers, with game paraphernalia and with facilitators, and thereby increasing stakeholders' capacity to communicate and collaborate	[14,60,66,67]
Realistic	A serious game must have a certain degree of realism allowing for participants to develop a deeper and richer understanding about the larger system that they are a part of	[15,54,64,73]
Low risk and safe environment	Offering risk-free opportunities for experimentation that carry no direct consequences for the outside world while supporting the integration of knowledge about the system	[14,60,66,67]
Multi-player role-play	Allowing participants to play different roles with the aim to develop a much deeper understanding of varying stakeholder interests and perspectives, stakeholder dynamics and power plays	[53,62,63]

2.3. Existing Serious Games for Water Management and Water Spatial Planning

There are many examples in non-water-related sectors of the adoption of advanced technology to foster interactive learning. The water sector has only begun exploring the application of computerized game simulations over the past decade [13,15]. This growth trend has, not surprisingly, coincided with an increasing implementation of integrated and adaptive concepts for water resources management involving principles such as bottom-up, multi-stakeholder participation and holistic systems-wide analysis [74]. In the context of water governance, the serious games developed to date are primarily aimed at building awareness and developing a shared understanding of common problems and trade-offs [53]. Examples of recent serious game simulations developed for water resources management and water-spatial planning include: Aqua Republica; CauxOperation; the Climate Game; EMOVER; Marine Spatial Planning Challenge; Shariva, and; the UVA Bay Game [14,15,73,75,76]. Some of these games involved stakeholders directly in the game design, including underlying systems and assumptions, while others have involved users only in the end-stage game play.

The Marine Spatial Planning Challenge is an example of an end-stage game play that offers an interactive game simulation involving stakeholders from different sectors to address complex, transboundary spatial development and water problems [14]. An example that involves stakeholders in the game design is CauxOperation, an agent-based multi-player role play game where users collectively designed and played a game to assess runoff and soil erosion issues in a French watershed [77]. Using the Companion Modeling ("CoMod") approach, Souchere *et al.* [77] combined scientific expertise and socio-political interactions in the CauxOperation game to enable users to understand complex bio-physical relationships and trade-offs. Another CoMod implementation is called Shariva (Thai for "shared river") and involves a serious game designed and implemented by researchers with the aim to create awareness, upgrade knowledge, build capacity and promote cooperation amongst stakeholders of an imaginary basin in the transboundary Mekong River. Game play was preceded with several pre-game training workshops designed to orientate players to the game context, teach negotiation and Alternative Dispute Resolution (ADR) skills, and provide training on tools to address and resolve transboundary conflicts. These workshops proved instrumental in achieving the game goals while also creating a positive learning experience. One of the objectives of the game was to develop an understanding amongst players of the viewpoints and interests of other players. The researchers designed the game to cause participants to switch roles during the game. For example, the same participants investigated two issues during the same game—one from the perspective of a fictional Flood Assessment Group and the other from the perspective of a fictional Shariva Expert Group. Despite the positive learning that occurred during this exercise, researchers observed that role-switching caused a degree of confusion amongst some of the participants [78].

The UVa Bay Game is an example of a participative computerized game that uses facilitated, round-based role play among a number of players who make decisions affecting their economy and their watershed [76]. Depending on the game, players assume the role of a stakeholder in a watershed or catchment. In each game, players must choose between only a few decisions during any single round. When the underlying models combine these decisions with those made by other players, the consequences can often be unexpected. Key to each of these games are the facilitated interactions, information sharing and negotiation that occur amongst players before, during and/or after rounds. Another game simulation called AquaRepublica is technically a one-player game simulation, although it can be played in the form of a competition between participants while allowing to monitor and track learning progress, as well as engage participants' interest and discussions [15]. The UVa Bay Game and AquaRepublica differ also in how they use computing technology. The UVa Bay Game uses a series of 51,000 differential equations to model inter-relationships between system variables with the primary purpose to scale up the rapid calculation of a larger set of variables affecting the watershed and its stakeholders—and not necessarily to create a more visually immersive environment. In its current form, the UVa Bay Game's game user interface is more akin to a computer "dashboard" than the virtual 3D world found in many medical and healthcare sector serious games [79]. Aqua

Republica, on the other hand, uses technology to create a visually engaging web-based interface and game play environment in addition to processing the calculations of the underlying physical and social models [15].

As mentioned, the Marine Spatial Planning Challenge involves considerable social interaction between stakeholders and is supported by a simulation model running in the background and a feedback system for measuring performance and enhancing learning [14]. Another interactive simulation, the Climate Game, integrates role play and scientific modelling and was developed to reveal and offer access to knowledge relating to climate, water and spatial planning, with the capability of calculating the measures taken by players in real time; this makes it easier for water managers and area developers to re-develop deltas and river areas in response to climate change (Ibid.). Zhou [14] found that although some game artefacts are more simplistic, involving no role playing, gaming interface or an immersive 3D virtual reality, these games may in some cases be more effective in facilitating real-world stakeholder collaborations than more sophisticated simulations. This study of several game simulations concluded that certain critical conditions relating to stakeholder commitment, consent, and equality were more effectively supported through simpler game artefacts in the establishment of a playful environment. It is essential to study in more depth how the involvement of stakeholders in the game design may impact the effectiveness of such games in general.

Several authors [14,16,77] emphasize that more research is needed on design principles, exploring appropriate serious games for complex water issues, and assessing the impact of these platforms on social learning and stakeholder collaboration for sustainable governance. It should be noted that various factors may work to undermine the beneficial impact of interactive processes, including: (1) power imbalances amongst players; (2) hidden agendas; (3) unequal stakeholder representation; (4) the inability to deal with fundamental value differences; (5) an overly simplified simulation that fails to offer a realistic and believable game environment; and (6) the occasionally perverse outcomes of consensus rules [80–82]. Maas [80] also comments that the quality of the stakeholder participation must be considered when designing, implementing and facilitating an interactive process as part of a serious game. It is clear, however, that the combination of declining cost and rapid growth of more powerful computing technologies (*i.e.,* artificial intelligence, virtual worlds, more sophisticated 3D engines incorporating real-world Geological Information Systems (GIS) data feeds, haptic devices, mobile computing, crowd-sourcing *etc.*) will continue to spur innovations in serious gaming—both within and outside the water sector.

3. Research Methodology

The objective of this study is to identify and assess the effectiveness of current social learning practices for transboundary management within the St. Lawrence River watershed. The study forms part of a much larger project that will explore the role and value of serious games to enhance social learning and collaboration processes for sustainable governance. In particular, this paper focuses on the following research themes:

1. *Stakeholder characteristics and institutional setting*, including stakeholder preparedness to participate, available resources, as well as their ability and willingness for critical self-reflection on positions and goals.
2. *Stakeholder interactions* and the way such processes are organized, while looking specifically at whether key stakeholders are involved, diverse interests, views and information are respected, potential solutions are developed and assessed, decisions are taken and implemented jointly, problem perspectives are exchanged, and ongoing reflection is facilitated on positions and goals.
3. *Stakeholder relationships* and their attitudes towards each other, involving strong relationships through repeated interactions, mutual trust, recognition of interdependence, and sharing of goals.

Interviews were conducted in the summer of 2014 with a total of 10 key stakeholders involved in water governance of the St. Lawrence River. These key individuals were identified in consultation with

the coordinator of the Regional Round Table for the Upper St. Lawrence and Greater Montreal area. Although a snowball sampling method was used to identify a much more extensive list of relevant stakeholders, practical constraints to this first study demanded that the researchers focus primarily on a smaller group of interviewees with the most significant experience in watershed management of the St. Lawrence River context, while at the same time representing some of the key stakeholder groups that operate at different management levels. Due to this constraint in time and resources, the researchers focused primarily on stakeholders in Ontario and Québec. In future research, the researchers will include a much wider and more diverse group of stakeholders in their research activities. While this study forms a first step in a larger three-year partnership development project, this paper reports findings of the first wave of data collection and, as such has as one of its aims, to identify possible avenues for subsequent waves of data collection. A profile summary of the research participants is provided in Table 3. Names have been omitted to respect the anonymity of the participants, but details of the principal relevant geographic location in which they work and organization type have been included.

Table 3. Overview of profiles for research participants.

Participant Number	Geographic Location	Organization Type
1	Ontario	Binational
2	Ontario	Non-governmental organization
3	Québec	Governmental/regulatory body
4	Québec	National, not-for-profit
5	Québec	Not-for-profit
6	Québec	Higher education
7	Québec	Non-governmental organization
8	Québec	Not-for-profit, government-recognized
9	Vermont	Non-governmental organization
10	Québec	Binational coalition

The interviews, on the whole, followed a semi-structured interview schedule using probing and follow-up questions as required to add clarity to responses. The questions that were asked were aimed at developing an understanding of elements that are required for effective social learning. A "template approach" [83] was used in which relevant text segments from transcripts of the interview recordings were categorized under "codes" and "themes" that were selected *a priori* based on the key elements of social learning processes that were identified in Section 2.1 and Table 1. With the exception of one interview that was conducted via Skype, the interviews were conducted face-to-face and tape-recorded with the consent of the interviewees. Most interviews were conducted in English, although two of the interviews were conducted primarily in French. Interviews were transcribed in the language they were conducted in and then translated when required. Subsequently, responses were coded to group these responses according to the elements of social learning, as well as for any emergent themes. Responses were identified and analyzed using direct content analysis, and a discursive construction was used to assess the degree to which required conditions and elements for social learning are in place for the effective transboundary management of the St. Lawrence River.

4. Research Context

In the context of transboundary water issues, both the strength and weakness in dealing with such issues lies within the great potential to help in negotiation between governments and non-governmental stakeholders, and existing incentives for stakeholder cooperation [22]. Although the United States and Canada are renowned internationally for their ability to cooperate and resolve transboundary water issues as they arise [84], it should be noted that the structure of the Canadian political system relating to water resources management is provincially dominant, creating a point of conflict between the United States delegations and Canada, as the US system relies on the dominance

of the federal government [85]. In other words, the states must cede negotiation in transboundary discussions regarding water issues to the federal level, whereas the provinces in Canada do not. There are over 300 transboundary lakes and rivers along the United States–Canada border, and water has been a defining issue in relations between the two countries. There have been many treaties and agreements regarding the usage and passage of water between the United States and Canada. The first of particular importance here was the 1909 Boundary Waters Treaty, which established the International Joint Commission (IJC) as the mechanism for conflict resolution should disputes arise over the use of transboundary waters.

In addition to the establishment of the IJC, which functions as a centralized commission to address transboundary water issues and manage conflict resolution, a number of legislative instruments and agreements have also been passed specifically to regulate use of waters from the Great Lakes. These include the Great Lakes Basin Compact of 1968, the Great Lakes Water Quality Agreement, which was first passed in 1972 and has since been renewed, and the Great Lakes Charter of 1985. The 1987 renewal of the Water Quality Agreement established 43 areas of particular environmental concern (AOCs) in the Great Lakes, five of which are transboundary. These agreements cover the Great Lakes and the international stretch of the St. Lawrence. As the St. Lawrence River leaves Ontario, just downstream of Cornwall, it becomes solely the jurisdiction of Québec and is no longer covered by these international agreements. This means that the transboundary lakes, rivers and streams that feed the St. Lawrence downstream of Cornwall are not covered by the Great Lakes Agreements. Bakker *et al.* [3,86] also emphasize that complications may arise in the transboundary management of the St. Lawrence River between Ontario and Québec because of a lack of coordination between the various governing bodies and the multitude of stakeholders involved.

In 2005, the Great Lakes–St. Lawrence River Basin Sustainable Water Resources Agreement was signed by the states and provinces surrounding the Great Lakes and St. Lawrence River. This agreement aims to strengthen participation of, and cooperation between, stakeholders in the region (with particular reference to data collection and sharing), and aims to adapt management models to changing climate conditions [87]. This agreement is enacted through laws brought in by each jurisdiction separately. The United States has implemented the agreement through the Great Lakes Compact, which was signed in 2008. The agreement was enacted in Québec in 2009 and in Ontario in 2007, though the regulations were only implemented in Ontario as of 1 January 2015 (Great Lakes-St. Lawrence River Basin regional body 2015). The past three decades have seen a shift from national to regional management of water resources in North America through the decentralization of governance [88,89]. There are now thousands of local, regional and special-purpose governing bodies who have the responsibility to govern some aspect of the regions water resources [90]. In Québec, for example, 40 watershed organizations have been established, each charged with planning and facilitating the implementation of watershed management plans within their own jurisdiction [12]. Ontario has put in place a similar governance structure, with 36 Conservation Authorities overseeing the water resource management across the province. Also of relevance here is Stratégies Saint-Laurent, a not-for-profit organization that oversees the *comités ZIP*, the committees of 13 priority intervention zones along the St. Lawrence that act to solve local ecosystem problems.

5. Results

In this section each of the research aims as identified in Section 2, are considered in turn with the goal of identifying insights that can be gained from the analysis of the interview transcripts.

5.1. Characteristics of Stakeholders and Institutional Setting

Although all interviewees recognized the importance of active participation between key stakeholders, the **fragmentation of jurisdiction and laws** has been highlighted as a key barrier to the effective involvement of diverse stakeholders in the transboundary management of the St. Lawrence River. Participant 2 (non-governmental organization), for example, identified fragmentation of

jurisdictions as a key barrier to effective transboundary collaborations and consequently social learning. The Great Lakes Water Quality Agreement covers only the international part of the St. Lawrence River and the part of the St. Lawrence River that is solely in Québec is excluded from this agreement. Where policies differ, efficiency is lost and issues can arise between the stakeholders in the regions. This participant also provided an example of the American eel to illustrate this point. The eel has a unique physiology and biology, and spawns in the ocean, but its normal habitat is upstream in Ontario. To make this journey, the eel must pass through two dams and eel ladders are provided for this purpose. Since 2008, the eel has been listed as an endangered species in Ontario, where restoration efforts are ongoing. The eel is not listed as endangered in Québec, however, and the eels are often caught along with fish. With the lack of a unified and common framework and the corresponding structure for collaboration, inefficiencies and disputes can arise in the region. Participant 4 (national, not-for-profit) emphasized, "*There should be a transboundary working group in charge of developing priorities, objectives, goals on specific issues related to transboundary water issues in the St. Lawrence River*".

In addition to the challenge of fragmentation, participants 1 (binational), 2 (non-governmental organization), 3 (governmental/regulatory body), 4 (national, not-for-profit), 5 (not-for-profit) and 9 (non-governmental organization) brought up **political will and commitment** as an essential element that forms either a barrier or driving force to the facilitation of transboundary collaborations. As participant 1 described, "*You've got folks who have absolutely no interest or connection or investment in the resource to folks who are very committed and invested and that extends politically as well in terms of those that are engaged and those that aren't*". This political will is emphasized as depending on the perceived seriousness and gravity of water issues at play, but is also often limited by a lack of civic engagement in water issues relating to the Great Lakes and St. Lawrence River. Participant 9 (non-governmental) highlighted, as an example, a record-breaking flood in Lake Champlain that prompted sudden stakeholder interest and involvement. "*When we talk about transboundary water governance*", explained Participant 4, "*we are not talking about day to day needs or, you know, a quick return on whatever you do*". This same participant suggested that the transboundary management of the St. Lawrence River requires a long-term vision and commitment that often do not coincide with the shorter term objectives and planning cycles of local or provincial government officials and organizations.

All participants cited **limited time, funding and resources** as barriers to working in greater coordination with their stakeholder counterparts. Participants 4 (national, not-for-profit) and 5 (not-for-profit) referred to a lack of resources to implement face-to-face meetings as inhibiting communication. Participant 5 explained that "*we have so much to take care of that we don't necessarily have time to sit around the table with others. There is not enough funding, not enough resources, to better our management practices*". Participant 4 spoke specifically of "*an erosion of scientific capacity*". All participants clearly recognized the importance of pooling resources and sharing knowledge between stakeholders in order to develop more sustainable solutions and outcomes. Participant 4 identified current high staff turnover in government agencies as a barrier to building the long-term relations needed for successful collaboration and social learning. This participant noted that "*while workers used to stay in jobs for life, that is much rarer now*". Participant 10 (binational coalition) spoke of concerns that many knowledgeable and well-connected people within governmental organizations are approaching retirement age, and that this may present challenges for further transboundary collaboration in the future. Participants 5 (not-for-profit), 6 (higher education) and 8 (not-for-profit, government-recognized) described the impact that language barriers are having on relations between Québec and neighboring provinces and states. According to Participant 5, the lack of bilingual people and resources to translate project documentations impedes the effectiveness of communication in the region. All participants discussed the problem of enforcing existing laws and regulations, and of implementing joint decision-making, both limited in large by a lack of funding and resources as well.

5.2. Stakeholder Interactions and the Way this Engagement Process is Organized

All participants referred to the **level of interaction and communication** between the federal governments as adequate to good. None of the participants highlighted communication between federal governments as a particular issue. Participant 4 (national, not-for-profit) went on to add that communication between federal governments was formal and largely directed by the IJC. At lower levels of government, however, the majority of participants highlighted deficiencies in communication between provincial and state departments. Participants 4 and 8 (not-for-profit, government-recognized) described relations between the states and provinces as operating in "silo mode". Participant 4 provided the example of the St. Lawrence River area of concern at Massena, New York, and Cornwall, Ontario, and stated, "*Whilst the region has been designated as a focus for transboundary management by the Great Lakes Water Quality Agreement* (i.e., *a federal agreement), in practice the State of New York and Province of Ontario have separate remediation plans and proceed towards the overarching goals independently*". Participant 3 (governmental/regulatory body), in contrast, described interaction as good at all levels of government and between stakeholders from non-governmental organizations. Participant 1 (binational) mentioned that, "*The larger the scale of the planning effort, the more difficult it is to get stakeholders engaged and the more difficult it is for them to relate their own particular interests or objectives to the issues being discussed at the larger scale*". This same participant emphasized that many collaborative processes at such larger scales require adequate human resources and change makers at different levels communicating effectively, while developing a clear shared vision for a process and outcome.

A number of participants highlighted *the issue of engagement of the public* in transboundary water management. Public participation was widely regarded as desirable, but participants 4 (national, not-for-profit) and 5 (not-for-profit) spoke of the way it was generally lacking in practice. The preoccupation with what was going on in their people's own back yards and individualistic values were cited as possible reasons for this. Participant 1 (binational) was of the opinion that grass roots passion has declined in recent years but also spoke of some knowledgeable, committed and professional stakeholders that do engage in the processes. This participant explained that, "*It is difficult for citizens and the public to have access to information on what is planned and what has been done and by whom*". Participants 4 (national, not-for-profit) and 7 (non-governmental organization) spoke of the way that the general public loses interest when scientists and politicians present differing perspectives of problems. Several participants referred to the mandate of the IJC to engage citizens in transboundary water resource management processes. In fact, the only vehicle for hearing public views and opinions on transboundary matters identified during the interviews was the IJC's calls for public consultations. According to participant 4, however, "*Last year there was an opportunity for the IJC to consult on a new regulation plan for Lake Ontario—St. Lawrence River. So you are talking about half a day, and with a dozen people in the room. So that's not much of a consult really*". Conversely, Participant 10 argued that the IJC did make an effort to be inclusive. Many of the participants referred to a need for increasing direct communication with communities.

During the interviews, participants were asked who, in their opinion, are the most powerful stakeholders. They were also asked to comment upon the **nature of the power held by different stakeholders**. Most participants agreed that decisions are made primarily at the federal, provincial and state levels (who hold the ultimate regulatory power), and that regional and local stakeholders are much less involved in decision-making processes. The balance of decision-making power with regards to treaties and negotiations in transboundary discussions is with the provinces in Canada and the federal government in the United States. It was also widely noted that the IJC holds a particular regulatory power on the specific topic of water levels and flows. Power over funding and resources was also widely attributed to governmental organizations. Participant 5 (not-for-profit) specifically discussed power in terms of expertise and knowledge, and attributed this to the ground based organizations who have been collecting data and building relationships with local stakeholders over the years. This participant explained that these grassroots level organizations are put in place to represent local stakeholders and the public in general. They shared that these organizations often

feel like their expertise, knowledge and perspectives are not sufficiently taken into account at higher levels and scales, and explained that to an extent, "*The citizen's voice isn't taken into account because large stakeholders have so much power and influence*". Participant 4 (national, not-for-profit) also noted that, "*First Nations communities, and their traditional knowledge, are not getting the responsibility and recognition that they deserve for transboundary water management*".

There was widespread agreement among the research participants that the **decision-making process is largely top-down**, although the participants presented a variety of different ideas regarding the basis upon which these decisions are taken. Participant 1 (binational) described how, "*Agreements are more formal and comprehensive, and resources are more transparent at the bi-national, federal, provincial and state levels, but when you move to provincial, regional and local levels, collaboration is much less comprehensive or ongoing, and more on a one-off basis through a specific project*". Participant 1 argued that decisions were driven by the commitments made by federal-federal and federal-state/province agreements. Participant 2 (non-governmental organization) spoke of the role of scientific evidence and public opinion in decision-making. They provided the example of the Water Level Plan of 2014, in which an early proposal based on scientific evidence was adjusted following public concerns about water levels and erosion in the Port of Montréal. Participant 5 (not-for-profit) argued that decisions are weighted too significantly in favor of large stakeholders (for example, large hydropower companies). In their opinion, large stakeholder concerns are the primary basis on which decisions are taken. Participants 6 (higher education) and 10 (binational coalition) also identified stakeholder concerns as a key factor in decision making processes, with Participant 10 saying that scientific knowledge plays a role in the background but that decisions are taken through negotiation by stakeholders.

Opinions also varied on the **extent to which decisions are taken collaboratively**. Participant 5 (not-for-profit) said categorically that they did not think that a collaborative decision-making structure exists. Coming from an organization with strong connections to the general public, this participant lamented the fact that, "*Decisions are made under the table and then when we present them to people because we want to consult them, we are doing it on the basis of the decision is already made*". Participant 8 (not-for-profit, government recognized) felt that their organization was not consulted as much as it should be. Participants 1 (binational), 2 (non-governmental organization) and 7 (non-governmental organization) expressed the view that decisions were made at the federal, state and provincial level, but that input was sought from local actors. Participant 1 said, in reference to individual citizens, they did not always get to make decisions but that there was an opportunity to be heard. Nobody argued that local actors and members of the public had any role in decision-making beyond presenting opinion, and everyone agreed that the role of the public and local actors could beneficially be strengthened.

5.3. Quality of Stakeholder Relationships

As the research data reveals, there are limited examples of social learning occurring through the majority of the St. Lawrence River Basin. With the exception of the highest levels of government (*i.e.*, federal government) and isolated localities, all but one participant described how there is **little interaction between stakeholders** involved in transboundary water resources management. Even where stretches of the river do come under the purview of the Great Lakes Agreement (*i.e.*, the international stretch between Lake Ontario and Cornwall, Ontario), little transboundary interaction occurs between the states and provinces. In this case, participants reported individual agencies operating in "silo mode", both pulling towards the goals as set out in the high level strategic plans but doing so independently. The overarching agreements help align the objectives of the transboundary parties, but without implementing significant processes for interaction and collaboration, little social learning can occur. Participant 9 (non-governmental organization) explained that "*every agency of government should really connect at the local level with organizations and people who are living in the watershed area*". They emphasized that their particular basin program has been successful due to regular meetings of their steering committee over the years, which allowed for different stakeholders to get to know each other, develop stronger relationships and ferment trust.

Participant 9 (non-governmental organization) presented a number of examples with clear implications for successful social learning in the region. In the Lake Champlain Basin, which is a shared resource of Québec, New York and Vermont, Canada and the United States had been individually collecting their own water quality data in their own territory. Each of the jurisdictions had developed a very rigorous testing program, but the problem was that the protocols for testing differed and as a result the data was not comparable, which limited a complete understanding of what was going on with regards to water quality in the lake. The three jurisdictions have collaborated effectively to find a solution to this problem by **aligning data collection methods** in Lake Champlain. Now, when data are collected, the samples are split between the jurisdictions and each runs tests on samples from across the lake following the same protocol. As a result of a change in problem framing from a local (*i.e.*, the state or province's section of the lake) to a global (*i.e.*, whole lake) perspective, a more complete understanding of water quality issues has been gained. This change in problem framing is a clear example of social learning occurring. The experience of such a positive collaboration is likely to have strengthened relations between the jurisdictions, enabling further collaboration in the future.

In another example, Participant 9 (non-governmental organization) described the reaction of journalists from Québec and the United States following a flood event in Lake Champlain. Both sides of the border held the impression that water level management decisions of the other jurisdiction had been the cause of the flooding and subsequent damages in their own territory. Underlying this issue were widely held misconceptions about the locations of dams in the region and the actual impact that operation of the dams has on water levels. In fact, neither jurisdiction had taken decisions, which negatively impacted the other. **Workshops were held to increase understanding** of the Lake Champlain dam system and management and its consequent impact on flooding. In this example, the learning is clear; members of the public increased their understanding of water level management in the basin. In contrast to the previous example, which occurred at the level of government agencies, this example involves learning between citizens. There is a social dimension to the problem due to the fact that the problem was causing ill feeling between communities and their neighbors. The strength of the social dimension with respect to learning for this second example is presently unclear. It is not clear from the interview transcript exactly how the workshops were conducted. It is important to explore this further, to establish whether citizens were brought together from the different jurisdictions, and to determine the process and extent to which social learning actually occurred.

All the interview participants **clearly recognized their interdependence** with other transboundary stakeholders in the region. Despite this recognition, the participants agreed that most stakeholders function too much in silo mode. Participant 4 (national, not-for-profit) provided an example of the Province of Québec that has developed the St. Lawrence plan which stimulates an effort for collaboration between the federal and provincial levels. When this St. Lawrence plan is matched with the Canada-Ontario Agreement program for the Great Lakes, however, these two plans are not at all integrated, while only matching certain priorities. Despite this lack of a current integration of plans and actions across different jurisdictions and boundaries, this participant is convinced that "*If the means and resources would be there for us to collaborate and interact, it would be much more ongoing and constant*". Participant 9 (non-governmental organization) stressed that "*If you want to get real about solving your water issues, you've got to solve the problem where it happens and you've got to be looking on both sides of the border*". This participant stated that this would be achieved not through new formal structures, but through the development and facilitation of new collaborative partnerships between stakeholders at different levels and scales. Another issue highlighted by two of the participants was the perception that the general public lacks understanding of their dependence on each other, both in their own provinces and states, and outside. Participant 4 (national, not-for-profit) said explicitly that they were unsure whether the public in their area of work knew where their water came from or of the impact that upstream states and provinces had on their water.

All of the participants described **reasonable working relations and trust** between government agencies at the federal, state and provincial level. Participant 10 (binational coalition) described

trust between individuals involved in transboundary collaboration as stronger than the resulting trust between the organizations they represent. Participant 9 (non-governmental organization) noted that, in their experience, the trust between Québec and Canada is not as strong as that between the other provincial and state parties, citing historical events as the probable cause. This participant also highlighted that trust of citizens in their government is very low due to the unwillingness of those government organizations to make tough decisions, stating that "*many citizens don't trust their state or their province to be doing the best thing for water quality*". Participant 4 (national, no-for-profit), referring to attitudes between government agencies, expressed the feeling that "*the doors are open for collaboration*". When it comes to developing mutual trust, Participant 3 explained, "*Trust is long to build and quick to disappear which is why you have to be very careful when addressing issues. When all stakeholders are around the table it is very important that there is no denial of certain issues or perspectives*". Three of the participants made references to tensions in the relationships between First Nations communities in the region, with Participant 2 (non-governmental organization) explicitly describing the way levels of trust held by members of the Akwesaske community in government officials varies.

6. Discussion

Although certain examples of social learning occurring have been identified during the interviews, preliminary results strongly suggest that these examples are the exception rather than the rule, and that on the whole social learning and transboundary stakeholder collaborations are not occurring to their full potential. The positive examples brought up by some of the interview participants all refer to events that occurred in the Lake Champlain area. Although these examples clearly highlight the fact that social learning is possible in a transboundary watershed context, and that really positive benefits can be realized, it should be noted that Lake Champlain is exceptional in the region, in that it has been designated as one of seven demonstration watersheds worldwide within the UNESCO Hydrology, Environment, Life, and Policy program. For these reasons, the examples of social learning that were identified are hypothesized to be exceptions rather than an indication of broader social learning routinely occurring throughout the region. Further work is proposed, employing a case study approach, to look in more detail at the successes achieved in the Lake Champlain basin. The goal of this further work will be to analyze these successes to identify the mechanisms that made them possible, and to explore the extent to which these successes may be replicable in other basins in the region.

It may come as somewhat of a surprise that more stakeholder interactions do not occur in locations within the St. Lawrence where the objectives of the transboundary agencies are under the purview of and in alignment with overarching strategies and objectives of the Great Lakes Agreement. Clearly where two agencies are working towards different goals, communication will be impeded by differing agendas. When objectives are aligned, however, it seems intuitive that it is in the best interests of both parties to collaborate. Table 4 below provides a summary for each category of analysis, indicating the key barriers to social learning and stakeholder collaborations that have been identified through the interviews. The findings are discussed, as well as their implications for transboundary watershed governance of the St. Lawrence, while also exploring potential solutions that serious game simulations may offer to address the barriers to social learning and stakeholder collaborations that have been identified within the study context.

Table 4. Summary of barriers to social learning for transboundary water governance.

Research Themes	Barriers to Social Learning
Characteristics of stakeholders and Institutional Setting	• Fragmentation of jurisdiction and laws • Varying levels of political will and commitment • Limited time, funding and resources • Erosion of scientific capacity • Loss of knowledge and expertise due to high staff turnover
Stakeholder interactions and the way this engagement process is organized	• Lack of a unified and common framework and corresponding structure for collaboration • Top-down approach to decision-making • Limited civic engagement that prompts political will and stakeholder interests • Lack of involvement of First Nations • Limited participation of non-governmental stakeholders
Quality of stakeholder relationships	• Limited stakeholder interactions • Power imbalance between stakeholders at different levels • Language barriers

6.1. Characteristics of Stakeholders and Institutional Setting

Overall, participants cited limited time and financial resources as barriers to working in greater coordination with their counterparts. Participants agreed that the challenges they face in their own areas often leave them with limited time for transboundary communication and collaboration. Although all participants recognized that increased collaborations may provide opportunities to pool resources, share knowledge, and work more effectively, a fragmentation of jurisdiction and laws, as well as varying levels of political will and commitment impact the extent to which transboundary stakeholder collaborations take place. It may be argued that there is a high degree of initial effort involved in setting up inter-agency networks and stakeholder collaboration processes, and that this barrier must be overcome before interactions can be fruitful and benefits reaped. Exploring and analyzing innovative mechanisms and interventions that support the facilitation of transboundary stakeholder collaborations and support social learning are therefore essential.

Social simulation and computer-based role-playing games can help stakeholders build their capacities by exploring skills, methods, and concepts rapidly within an engaging nonthreatening environment ripe with experiential and behavioral learning components [62]. Serious games can also be viewed as powerful new means of communication, and an even more powerful means of persuasion while offering an opportunity for innovation to policy makers [14]. In light of this study, it is also important to explore in more detail how such games may offer mechanisms to effect change in social behavior as well as in political ideas. Due to the mention of limited time, resources and funding highlighted by all research participants, it seems essential in this case to offer a serious game simulation that is not only interactive, but also provides immediate effects and output based on participants' input [14,60].

6.2. Stakeholder Interactions and the Way This Engagement Process Is Organized

Transboundary engagement in the region, with the exception of isolated localities, is limited to top levels of the federal government and occurs in a formal manner, coordinated by the International Joint Commission. With such little transboundary agency interactions and communication, it is no surprise that collaborative decision making is not occurring on the whole at the state/provincial level.

In those regions which are covered by the Great Lakes Agreement, this is likely to lead to inefficiencies in management strategies. In the majority of the St. Lawrence River Basin where the influence of over-arching agreements does not appear to be felt as yet, this is likely to lead to a situation where the different jurisdictions enter a cycle whereby they take decisions separately, which leads to a lack of co-ordination of objectives, creating barriers to effective communication, thus further reducing the ability of the agencies to take decisions collaboratively. While there is still a very top-down approach to water governance of the St. Lawrence River with limited interaction and communication at lower levels of government, and with stakeholders from non-governmental organizations, it is important to find ways to scale up collaborations and learning across the basin. Serious games present a promising, bottom-up tool through which stakeholders at different levels may gain an appreciation of the larger context in which they are operating [32]. Serious games have been found to be ideally suited to applications in contexts in which complex, interconnected problems require reconciliation of divergent viewpoints [62]. It has been argued that they allow players to co-develop knowledge through experimentation but without real world consequences [15]. Although serious game simulations may offer support in the development of initial interactions and connections between stakeholders that do not collaborate in real life, it must be studied further whether such interactions will be able to establish longer term learning partnerships and stronger stakeholder relationships.

The social learning paradigm is concerned with the extent to which knowledge is able to flow in multiple directions. Such learning is meant to occur between a broader range of stakeholders than just governmental and non-governmental agencies. The interview data suggest that the relationships required to enable social learning are very limited between the general public and governmental agencies, and the First Nations and governmental agencies, and also to an extent between non-governmental and governmental agencies. During the interviews participants highlighted a number of issues with regards to the participatory role of the general public in transboundary water resource management. Despite some examples of citizen engagement, the public on the whole was characterized as disengaged. Correspondingly, the degree of transboundary collaboration in decision making for the St. Lawrence River may be considered low, falling somewhere between an "Expert Authority Approach" and an "Inquisitive Approach" on Lauber and Knuth's [30] participation scale. In order to develop increased stakeholder interactions, it is crucial to understand what mechanisms and tools may support this in addition to more conventional ways of stakeholder interactions (*i.e.*, meetings, emails, phone calls, *etc.*). One way to increase stakeholder interactions is through the involvement of stakeholders not in only the game play, but also the design and development of a game simulation. Gurung *et al.* [91], as an example, involved their study participants in the process of developing the game they would later play, much like a collaborative modelling process. This not only helped to increase interactions, but also encouraged consensus building regarding the facts of the underlying system, as well as the development of a shared vision and goals.

6.3. Quality of Stakeholder Relationships

Mostert *et al.* [8] identified the recognition of mutual dependence and trust between stakeholders as important prerequisites to social learning. The results of this study show that interviewees recognize the mutual dependence between key stakeholder groups. Interview participants also spoke of high levels of trust between governmental and non-governmental agencies at all levels. For effective transboundary collaborations, such good relations and trust must be developed with a much wider group of stakeholders at all levels. While the interviews have been conducted primarily with representatives from governmental and non-governmental agencies, it is important in future research to explore the relations and dynamics with diverse stakeholder groups further to gain a greater understanding of their perspectives on the issues at hand. Additionally, there was one mention of strained relations between Québec and Canada, which is a well-known historical problem that could be further explored in the context of transboundary water resources management in the region.

Serious games offer the opportunity for stakeholders to not only voice their perspectives, but have other stakeholders experience it themselves through multi-player role-game-play. Hagen [92] discuss how useful serious game play can be in developing trust and empathy amongst stakeholders for the problems faced by other stakeholder groups. Their study indicated not only a strengthening of relationships between diverse stakeholders through increased mutual trust and empathy, but also an improved understanding of the system and complex issues at play. This was also found by Gurung *et al.* [91] who asked farmers from villages in conflict over water allocations to play a simulation game in which the farmers swapped roles for one round of the game. They found that, "the scenario with swapped roles, during which upper villagers played the role of lower villagers and vice versa, was very effective at sharing different points of view".

7. Conclusions

Generally good relations between Canada and the United States create a context that is ideal for social learning to occur in the St. Lawrence River Basin. The findings from this preliminary study show that only limited examples of successful social learning and transboundary stakeholder engagement have been taking place in the context of the St. Lawrence River Basin. Transboundary stakeholder engagement in the region, with the exception of isolated localities, is limited to the top levels of federal government and occurs in a formal manner, coordinated by the International Joint Commission.

As there is little interaction at lower levels of government, the lack of social learning at these levels is not surprising. The isolated examples of social learning occurring demonstrate its potential for increasing the effectiveness of resource management in the region. Further work is proposed to analyze the mechanisms that enabled the identified examples of social learning and those which create barriers in other cases. In this way, recommendations can be made as to how social learning can be scaled up across the basin. Serious games present a promising, bottom-up tool or intervention platform through which learning partnerships and networks may be created that support the development of stronger stakeholder relationships, as well as increase interactions and communications between these diverse stakeholder groups.

This study is the first phase of a larger three-year project that is aimed at exploring the role and value of serious games to enhance social learning and collaboration processes for sustainable governance. With this research, the authors have identified a series of required elements for social learning (see Table 1) as a way to "test" for the utility of serious games in advancing social learning in the St. Lawrence River system. The second phase of this project entails the actual testing of existing game simulations with youth and students, as well as with stakeholders that operate in the St. Lawrence River through the Regional Round Table for the Upper St. Lawrence and Greater Montréal area. A unique game simulation will be development for the St. Lawrence River context that will be tested during an AquaHacking event that is to take place in October 2016 in Montréal, Canada.

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