Social simulations for behavioral change in urban sustainability contexts

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Abstract

In this paper, we propose that a special type of serious games – *social simulations* – offer a promising alternative to traditional awareness-raising or "educational" tools. We first introduce a definition of *social simulation* and describe its potential for triggering a behavioral change in the urban sustainability context. We then use examples taken from three social simulations focused on challenges and opportunities connected with city life, developed by the Centre for Systems Solutions, namely, *Bengaluru Quest,* which simulates collective policy-making in "the city of burning lakes," the *Sustainable Urban Heating Simulation (SUHS),* which encourages players to look for optimal urban heating solutions and reduce CO2 emissions, and the *Public Infrastructure Participatory Engagement Simulation (P.I.P.E.S.),* which simulates relationships among city officials and residents regarding water infrastructure management.

The paper demonstrates that, involving features of effective sustainability learning determined by the United Nations (such as e.g. the holistic approach to sustainability and the focus on critical thinking and participation), social simulations successfully engage wide audiences in discussions on urban sustainability. Based on collaborative problem-solving and decision-making processes, serious games and simulations enable players to explore sustainability principles, face emerging challenges, test and verify potential solutions, thereby transferring this knowledge into their specific, local or regional contexts. Moreover, face-to-face contact with people of various backgrounds and values trigger perspective-taking, trust building, commitment, and development of a shared understanding of a problem. In this way, collective and adaptive response to complex dynamics can be exercised in a stimulating, "playful" environment.

Keywords: urban sustainability, eco-city, green city, social simulations, serious games

1. Introduction

1.1. Towards an integrated approach to urban sustainability

Richard Register claims that "[c]ities are by far the largest creations of humanity. Designing, building, and operating them has the greatest destructive impact on the nature of any human activity" [28]. His words have never been more accurate than today. As reported by the United

Nations, occupying only 3 percent of the planet's land, cities account for about 70 percent of global energy consumption, carbon emissions, and resource use respectively, and in many urban areas of the world are home to socioeconomic inequalities, social exclusion, poverty and unemployment, slums and inadequate housing, etc. [42]. Taking these factors into consideration, it is expected that the faster and more expansive urbanization processes are, the more severe socio-economic and environmental pressures will be experienced, including shrinking freshwater resources, sewage mistreatment, poor living conditions, and deteriorating public health.

In the 1990s, the growing concern of the international community related to the negative consequences of rapid urbanization led to the concept of urban sustainability. Since that time, a number of global and European policy frameworks and strategies focused on sustainable development in urban contexts have emerged, including the UN Rio Declaration on Environment and Development [34], the Agenda 21 [35], the Habitat Agenda [36], the New Urban Agenda [38] or the EU thematic strategy on Urban Development [12]. Also, the Millenium Development Goals and their successor, the 2030 Agenda for Sustainable Development [39] incorporate urbanization in the broader framework of sustainability, formulating the goal on cities (Goal 11), known as the *urban SDG*, to "make cities and human settlements inclusive, safe, resilient and sustainable through eliminating slumlike conditions, providing accessible and affordable transport systems, reducing urban sprawl, increasing participation in urban governance, enhancing cultural and heritage preservation, addressing urban resilience and climate change challenges, better management of urban environments (pollution and waste management), providing access to safe and secure public spaces for all, and improving urban management through better urban policies and regulations" [42].

Efforts to innovate on urban sustainability are often reflected in planning and building so-called *green cities* or *eco-cities*. Although no common definition of *eco-city*, *green city* or even *sustainable city* exists, these are generally defined by an integrated approach, incorporating four pillars: social development, economic development, environmental management, and urban governance [40]. The interplay of these highly interrelated dimensions creates a complex multi-layered system characterized by dynamic changes and emerging problems that cannot be fully predicted and solved by simply addressing individual elements separately. Instead, they require recognition of links to other parts of the system [30, 13].

1.2. Sustainability learning

Many challenges exist to maintaining cities in a way that makes use of the potential synergies created by the four pillars of sustainability. The existing opportunities and challenges linked to urban sustainability are traditionally tackled at the institutional level, through formal decisions

and actions taken by national and local authorities in consultation with subject matter experts in designing, implementing and maintaining public space [19]. More often than not, these strategies and policies place the city's "hardware" at the center of discussions. For example, a review of the literature on city sustainability conducted by Shmelov and Shmelova [30] revealed that the main areas of attention in research in urban contexts include optimization of energy use and an introduction of renewable energy technologies, sustainability of urban transport systems, efficient waste management, and landscape architecture and design. Relatively less attention is devoted to social aspects of cities' development and functioning, such as environmental psychology, democratic participation, perception of space and quality of life, social helplessness or mutual aid. This is important because most problems in human settlements are generated and solved by people. As a result, an integrative approach to urban sustainability must reflect psychological and behavioral dimensions of urban sustainability (the general public's environmental consciousness, their ability to collaborate with others, as well as their attitudes and habits related to resource production, consumption, and discarding, to name a few) [30].

To enhance civic engagement and behavioral change, widespread sustainability awareness-raising activities are needed that are engaging, effective, and easily replicable. In this context, the United Nations [41] identified key features of successful sustainability learning: 1) *interdisciplinary and holistic* – rooted in and linked to other aspects of human activity and knowledge; 2) *values-driven* – capable of engaging “learners” in acquiring, examining, debating, assimilating and applying the shared values and principles underpinning sustainable development; 3) based on *critical thinking and problem solving* – leading to confidence in addressing the dilemmas and challenges of sustainable development; 4) *multi-method* – combining different active pedagogies (such as art, drama, debate, experience) rather than presenting facts to passive audiences; 5) *participatory* – “learners” have to be able to participate in decisions on how they are to learn; 6) *applicable* – the learning experiences should be integrated in day to day personal and professional life, and 7) *locally relevant* – addressing local as well as global issues and using the language(s) which learners most commonly use.

Serious games and simulations are gaining recognition as a promising way of addressing these features while engaging wide audiences in discussions on sustainability in urban contexts. Based on collaborative problem-solving and decision-making processes, serious games and simulations enable players to explore sustainability principles, face emerging challenges, test and verify potential solutions, and transfer this knowledge into specific, local or regional contexts. In this way, collective and adaptive response to complex dynamics can be exercised in a stimulating, "playful" environment.

2. Social simulations for addressing sustainability challenges

In this paper, we propose that a special type of serious games – *social simulations* – offer a promising alternative to traditional awareness-raising or "educational" tools. We first introduce a definition of *social simulation* and describe its potential for triggering a behavioral change in the urban sustainability context. We then use examples taken from three social simulations focused on challenges and opportunities connected with city life, developed by the Centre for Systems Solutions, namely, *Bengaluru Quest,* which simulates collective policy-making in "the city of burning lakes," the *Sustainable Urban Heating Simulation (SUHS),* which encourages players to look for optimal urban heating solutions and reduce CO2 emissions, and the *Public Infrastructure Participatory Engagement Simulation (P.I.P.E.S.),* which simulates relationships among city officials and residents regarding water infrastructure management.

Social simulations, like all serious games, combine game elements with a serious goal (e.g., to guide skill or knowledge development). The outcome of playing serious games should thus be advantageous for a player, firstly by enabling a learning experience and secondly by not having negative impacts, such as increased aggression or addiction [11]. Learning through social simulation differs significantly from traditional knowledge acquisition, like that based on textbooks and lectures because rather than depending on presenting facts or diagrams to passive "learners," social simulations employ what is referred to as *procedural rhetoric* [5] – game design features that aim to create spaces that mimic real-world processes and that can be actively explored by players. Through the use of symbolic representations like roles, problem cards, tokens, and dice, players can, for example, actively discover the interrelations between different sustainability challenges, establish in-game allies and partnerships and "play out" possible scenarios for implementing new city policies. All this happens via the game's *embedded design,* relying upon active problem-solving and emotional engagement rather than on direct persuasion or moralizing [5].

Social simulation involves yet another important element: social interaction. In this type of activity, players are meaningfully engaged in something that could be compared to creative group scenario building, storytelling or role-playing [14]. Assuming new identity creates a room for understanding different perspectives and empathizing with people of different interests and values. It is especially important in the context of multi-stakeholder complex issues, such as urban sustainability, which involve as diverse groups of actors as public authorities, engineers, architects, planners, transport managers, activists or citizens, whose needs and priorities often overlap or exclude each other. Such liberation from regular social roles has yet another advantage, as it may help unlock players their creativity and develop unexpected and innovative remedies to problems that might have been considered insoluble [14].

Social simulations offer a playful yet transformative experience that is rooted in and based on one of the most characteristic elements of social life – drama. According to Victor Turner, *social dramas* are processes that are closely related to Aristotle's description of tragedy in the *Poetics* and occur within groups "bounded by shared values and interests" or "having a real or alleged common history" [33]. The beginning of a social drama is always manifested by a breach of a norm (usually performed by an individual or group that is empowered enough to challenge entrenched authority) that reveals the underlying differences in values or perspectives within a community, and – through an inevitable crisis and redress mechanisms – leads either to reintegration of the disturbed social group or schism. In each scenario, the resulting social reconciliation or separation brings about a noticeable transformation of values, influences, or social relationships [33]. Similarly, social simulations, entailing various participants and engaging them in joint problem-solving, create many learning opportunities, triggering self-reflection and independent critical thinking. In the next section of the paper, we will provide examples of three social simulations rooted in the urban sustainability context and try to illustrate how they may support players in the assimilation of urban-sustainability knowledge and development of mindsets that may affect a positive change in their behavior related to the city.

2.1. *Bengaluru Quest*

One of the main features of games and simulations is that they offer a temporary escape from everyday problems and concerns. An engaged player will momentarily lose interest in facts, objects, and people other than those that are directly linked to play. In addition to the liberating feeling of pleasure and excitement, this emotional and cognitive engagement or immersion offers yet another benefit – it preconditions a successful learning experience [17, 2].

This preoccupation with the tasks and situations occurring in a social simulation is possible through *immersive presence*, defined as "feeling of involvement and absorption, perceptually and psychologically in the [in-game] environment" [2] and *flow*, that is, "a profound enjoyment and concentration experience during activities in which a person's skills match the challenge of the task" [2]. Both are critical in simulation-based learning, as they enable players to get a very realistic feel that they are in a different world. This is what was referred to by Johan Huizinga as a "magic circle" [16] that is governed by its own rules and filled with symbolic objects – tokens, cards, boards, etc. – that may be touched, moved, exchanged, used as clues, explored, and thus exploited actively to better understand the principles underlying the in-game reality.

To illustrate how important personal engagement and immersion in in-game reality are in fostering players/learners interest in the urban sustainability-specific context, we will use the

example of *Bengaluru Quest*, a social simulation that explores the complex, ambiguous, and uncertain reality of modern policy-making, based on an example of the city of Bengaluru (until 2006 – Bangalore) in the state of Karnataka in southern India.

Often referred to as India's Silicon Valley, Bengaluru constitutes the country's major IT hub, accounting for about 38 percent of the IT exports from India [7]. With its gross domestic product predicted to jump 8.5 percent per year between 2019 and 2035, it is also one of the fastest growing cities in the world [23]. As home to leading national and international IT corporations (such as Google, Microsoft or Yahoo) and to the largest number of high-tech start-ups of any Indian city, this megacity attracts thousands of software engineers and IT specialists and seems to offer unrivaled opportunities [31]. However, like every giant, the city faces many problems associated with rapidly growing populations (4.04% per year in 2019 [43]) – social inequalities, scarcity of potable water and city greenery, poor sanitation and air and water pollution.

As might be expected, the flagship IT companies in Bengaluru are located in well-stocked city parts. Their managerial staff and qualified employees live in modern, gated communities. A large percentage of the city's population, however, inhabits slums (nearly 25 percent – around 3 million people in 2017) [27]. A recent multi-agency study on the state of slums in Bengaluru revealed that the city has over 2,000 slums, significantly more than the 597 that are officially recognized by the government [25]. Additionally, a long-term survey conducted by NGO Fields of View (FoV) shows that over 70 percent of the families in slums "live in debt and are trapped [there] with nowhere to go" [26]. The same survey reveals that nearly 80 percent of slum inhabitants originate from the socio-economically deprived Scheduled Caste and Scheduled Tribe communities [27].

While the city is expanding and well educated IT professionalists are getting wealthier, the socio-economic gap between the richests and the poorests is becoming wider. However, Bengaluru's problems do not end here, as the city is often mentioned among the top agglomerations struggling with drinking water scarcity [3]. Although Bengaluru experiences a lot of rain at certain times of the year, supplying its citizens with sufficient clean drinking water is difficult. Compensating for the lack of rivers nearby, the city used to rely mainly on wells and over 600 artificial lakes that were established in the 16th century. In the 70s, the city started pumping water from the River Kaveri that is located 100 km from the city (the river supplies nearly 60% of the city's demand for drinking water [24]). However, pumping is both costly and ineffective, as nearly 50% of water meant for the city is wasted in distribution due to leakages in the water supply system and unauthorized water connections [29]. The artificial lakes have mostly been converted into housing estates or other developments, further encroaching on both the city's water supply and on grounds that were once occupied by the city's greenery. As a

result, the water that does remain in these lakes is no longer suitable for drinking or bathing. In fact, sometimes the level of toxic contamination (mainly due to illegal incinerating and dumping of e-waste) is so high that the water reservoirs are covered with froth that catches fire [4]. Traffic and uncontrolled emission of industrial exhaust also contribute to this contamination and are cited as the primary reason why Bengaluru was ranked 63rd among 168 cities for PM 2.5 levels in 2015-16, far below standards prescribed by the World Health Organization [32].

With its multicultural and economically diversified population, water and air pollution and related problems, Bengaluru offers an excellent example of a complex, multifaceted system. To get to its underlying problems and to understand their interconnectedness, *Bengaluru Quest* developers conducted an in-depth evaluation of the context, collecting dozens of reports and articles on the city's situation. The process took several months and entailed a thorough analysis of the available data. Rendered into dry facts, the complex landscape of Bengaluru's challenges and opportunities seemed overwhelming and rather complicated, by no means offering an exciting learning opportunity. The simulation sought to address this directly, by eschewing these data-driven presentations and immersing participants in the chaos, enabling them to get a feel for the difficulty inherent in addressing all the overlapping and contradicting citizens needs.

With no more than a couple of words of instructions, the participants of *Bengaluru Quest* enter the roles of policy-makers responsible for the present and future of Bengaluru. The simulation is held in an open space or a large room that can accommodate up to 30 people, arranged in groups at six tables. Five of them, marked as *Water Department, Public Health & Waste Department*, *Infrastructure & Energy Department*, *Business Department*, and *Environment Department* may be located next to each other. The sixth table, moved a bit aside, is reserved for the *City Council,* which is responsible for processing policy proposals submitted by department heads.

The simulation is divided into two phases – the operation phase during which decisions are made, and the results phase that summarizes the city progress and displays the consequences of the newly introduced policies. During the operation phase, department members are continuously approached by moderator's assistants who deliver them thick piles of documents: claims, requests, and petitions from various interest groups and the dissatisfied society of Bengaluru. Based on this simplified but reality-inspired data, "requests from society" reflect the most pressing problems of the city: “Arsenic and heavy metals found in the groundwater pose threat to our kids’ health!” – reads one (in the form of an alarming newspaper headline). “Water theft must be stopped! It's harder and harder to provide water to our houses" – states another (stylized to look like an email from a concerned citizen). While some are formulated as open suggestions or kind request, others adopt a more demanding tone: "This is a call to the city council! Plant more trees to restore the green lungs of our city!” Some also present specific

solutions and try to lobby for them. They all have to be read quickly and prioritized. While time is running, the inflow of new problems does not stop, urging participants to make their decisions on appropriate policies under the growing pressure. After reaching a consensus, the head of each department leaves to pass their proposals to the council, and the result phase follows.

The participants of *Bengaluru Quest* have only one hour to embrace and address the piling up problems. Often dazed and confused at the beginning, participants are quickly emotionally engaged, experiencing stress, social discontent, and frustration, characteristics of real policy-making. Rather than analyzing the Bengaluru's situations from the outside, they are instantly immersed in it, facing emerging challenges and using their creativity and skills to address them. This experiential sensory exposure helps them identify with their new roles and take full responsibility over the in-game city, which is responsive to their actions and evolves in the direction determined by the policies they create: A simplified map of Bengaluru is constantly updated by the moderator during the results phase, reflecting the participants' decisions and the current state of the city. The simulation also enables more active and personalized learning as players have some control over what they decide to do and how they will cope with the consequences of their choices [2]. They are not always able to save Bengaluru – some policies bring unexpected consequences, other are erroneously targeted or contradict with solutions proposed by different departments – yet they are empowered enough to develop a sense of agency and responsibility of what happens around them.

For many participants of *Bengaluru Quest*, the 60 minutes during which they were completely "lost" and overwhelmed with numerous emergencies is a powerful lesson. As one of the players admitted, people often imagine that policy-making is a rational process in which all the actors have time and cognitive ability to process objective data, balance pros and cons, and evaluate each decision against the other. In *Bengaluru Quest* (and in the "real world") however, much more messy decision-making processes are used, enabling players to experience what is often referred to as "organized anarchy" – a collective decision-making model in which a decision situation is compared to a "garbage can" to which problems and solutions are dumped chaotically, creating a mix which, in turn, determines the decision's outcomes [10]. Time pressure, public mood, personal preferences, and biases all affect the quality of decisions, leading in most cases, to rather random policies that further complicate an already grim situation of the city. The in-game world in the *Bengaluru Quest* social simulation proves to be effective at capturing the reality behind policy-making, and revealing its true, messy character. At the same time, the safe environment of a "game", enables players to safely explore a number of possible future scenarios, make mistakes and draw conclusions that are not linked to any fatal consequences in real life.

2.3. *Sustainable Urban Heating Simulation (SUHS)*

While *Bengaluru Quest* offers players an immersive interactive environment to experience the difficulty inherent in making decisions under stress and uncertainty, *Sustainable Urban Heating Simulation (SUHS)* enables players to actively explore options for accelerating low-carbon transition in the area of urban heating. The simulation was developed by the Centre for Systems Solutions in collaboration with the International Institute of Applied Systems Analysis (IIASA), as part of the project *Addressing Energy Transition Gaps in Climate and Energy Model Regions of Austria Through Policy Co-Design,* funded by Klima- und Energiefonds. It serves as an example of the so-called *strategic simulation,* focused on a context-specific problem, in this case – Austrian energy transition.

Strategic simulations (also known as *policy exercises*), like all social simulations, employ models of simplified yet real-world situations to enable players to explore the existing interrelations within this system and formulate assumptions about "how things work" [5]. However, unlike social simulations that may be applied to many contexts and played by various groups of stakeholders to present a general concept (like in the *Bengaluru Quest* case: that policy-making is a complicated, messy endeavor), strategic simulations are problem-specific and user-tailored, and their success is measured by the emergence of a collaboratively negotiated, realistic and doable strategy to overcome an identified obstacle [14].

The *SUHS* multiple board-game is rooted in the context of Australian energy transition. Following the Paris Climate Agreement and commitments in the European Union, Austria has committed itself to an 80-95% greenhouse gas emission reduction by 2050. Achieving this goal entails far-reaching and unprecedented action in terms of scale; decarburization of European society and industry that requires significant contributions from public and private resources as well as widespread societal change. While public opinion polls show overwhelming support for climate change actions in Austria – especially for the innovative CEM program that backs community-based, bottom-up low carbon initiatives via information campaigns, subsidies, and tax breaks – this positive public attitude is not sufficiently reflected in decisive actions towards collective climate change goals. The SUHS simulation was created to supplement conventional information campaign approaches and help various stakeholders (local authorities, CEM managers and residents, business owners, etc.) to co-produce and test policy implementation options for accelerating the low-carbon transition, specifically in the area of urban heating [22].

In the *SUHS* simulation, an average Austrian town in one of the CEM regions is represented on the map. Unlike in *Bengaluru Quest,* which employed very simplified, symbolic references to real data and instead focused on reflecting the chaos and confusion related to multi-stakeholder decision-making, the emphasis in *SUHS* was on collecting and organizing actual data to engage participants (e.g. policy-makers and CEM residents) in a collaborative

process of building a model that is adequate to their specific context. The resultant model includes basic city buildings, such as single-family houses, multi-family houses and public buildings, which vary from modern to historical. Each building contains detailed information about types of energy operators, insulation and power that are needed to heat the building in the winter season. In this simulation, every participant plays the role of a city resident who is both responsible for her own household and acts as a member of the city council.

Participants are presented with the energy bills from five previous years and a pile of investment cards, and are encouraged to experiment with different budget options for their individual and public buildings. The relative freedom of their actions is limited by the simulation rules which – as this is a strategic simulation – are directly rooted in Austrian-specific regulations (e.g. a certain type of outside insulation cannot be introduced in historic buildings). Also, the time and space are compressed (participants of the *SUHS* simulation make decisions for five years), yet, the basic mechanisms and challenges presented and played out correspond to real processes and situations, enabling players to formulate analogies and propose solutions to the problems faced by their specific CEM region.

The *SUHS* simulation then consists of a series of operations and results phases, which trigger self-reflection and corrective action, fostering what is referred to as *double loop learning* [1]. Participants of this lively simulation are given feedback on their decisions almost immediately, as a computer program (managed by the moderator) calculates both the efficiency and the cost-effectiveness of their choices. When faced by frustrating or unexpected outcomes, players may easily modify their assumptions and base their subsequent decisions on a more sound recognition of a problem. Experiencing this decision-feedback cycle several times during one simulation session helps with verification of ineffective mental models and consolidation of new, more adequate strategies towards optimal urban heating options. Such active experimentation with solutions is more natural, rooted in intrinsic human curiosity and a "trial and error" process, by which direct experience is turned into knowledge [18]. It also marks a significant shift from a solely cognitive, "thinking first" model of learning and decision-making to a more "feeling", "seeing" and "doing" approach, in which a player becomes an active element of the environment and may freely explore its boundaries to form hypotheses about it that may later be verified and tested.

As a context-specific, strategic simulation, *SUHS* offers yet another unique advantage. The feedback generated by a computer program is based on in-depth research of heating options available in Austria, matched to the type and requirements of each building and consulted with experts. The results produced are therefore reliable, enabling participants to take a "virtual look into the future," make mistakes, observe impacts, and explore the unknown – all through an active process rather than purely "verbal speculation" [14]. Through their interaction with a

dynamically simulated reality and each other, participants shape, create and work to steer themselves into a “possible,” “probable” or “preferred,” future [8] gaining a direct insight into “how things work” and what results may be expected [5]. This “virtual look into the future” [14] is especially important in the context of urban sustainability, as many solutions aimed at improving the quality of life in urban areas (e.g. introduction of renewable sources of energy) entail considerable uncertainty as to whether the time, work and money invested will generate the desired outcomes. Fearing the future, people block their creative potential and become less open to combine “[...]experience with creativity to find a new, original, inspiring and appropriate pathway into the unknown.” Meantime, play is “a highly effective way to develop new combinations, which [...] are precisely what innovation requires” [14].

The *SUHS* simulation is still being tested, most recently in Graz, Austria in collaboration with the Wegener Center for Climate and Global Change. With its capacity to turn the abstract and unimaginable into a tangible consequence that can be interpreted, processed and successfully applied outside the simulation reality, it has considerable potential as a starting point for more in-depth discussions of how to bridge the gap between knowledge and practice in Austria energy transition.

2.4. *Public Infrastructure Participatory Engagement Simulation (P.I.P.E.S.)*

Social simulations, as their name suggests, have to "[...]offer a social experience, engaging people of different backgrounds and worldviews to constructively confront each other, learn to solve conflicts, and negotiate or empathize with each other" [9]. This social dimension of games and simulations presupposes that multiple people are engaged in the same activity simultaneously, and the number of players directly influences the complexity of game-specific interactions (usually, the more participants, the more complex the interactions) [13]. To see how this social aspect affects mutual learning and collaborative action towards a shared goal (in this case towards increased urban sustainability), let us take an example of yet another social simulation focused on urban sustainability – *Public Infrastructure Participatory Engagement Simulation (P.I.P.E.S.)*

P.I.P.E.S. was designed as part of a collaboration between Michigan State University and the Centre for Systems Solutions. The simulation explores the challenges and opportunities in managing drinking water in US cities and focuses specifically on trying to understand the extent to which public trust may have an impact on the effectiveness of this process. The inspiration for the simulation came from the water crisis in the city of Flint, Michigan (US) that faced a severe public health emergency due to lead contamination in the municipal water supply. This Water Crisis began in 2014 when the city switched its drinking water source from Lake Huron to the

Flint River. The change, intended to save money for the city, had serious consequences. Corrosion control chemicals were not applied to the now much more corrosive water, allowing lead from pipes, joints, and fixtures to seep into the water supply. The contamination affected thousands of residents and was blamed for an outbreak of legionnaires' disease, which caused 12 deaths in 2014 and 2015 [21].

The situation in Flint serves as an important reminder that America's water infrastructure is aging rapidly and, in many cases, is not adapted to the current needs. In the case of Flint, the water infrastructure was constructed for a city that was, at its prime, nearly twice its current size [15]. This Water Crisis also provides a perfect example of a breach that precedes a *social drama.* The Flint Water Crisis provoked public outcry and exacerbated a persistent distrust of, especially state government officials, with many activists and residents demanding that the Governor and regulatory officials be removed from their office and held criminally responsible [21].

P.I.P.E.S. was designed to address these topics and to highlight the nature and role of relationships among city officials, infrastructure managers, and the public. Participants in this lively simulation assume one of eight roles: mayor, infrastructure manager, the state department of environmental quality, journalist, and one of four city residents. The agenda of each actor differs: governmental actors (the mayor, infrastructure manager and department of environmental quality) strive to manage an underfunded water system, ensuring proper management, system repairs, fees and taxes that allow for proper drinking water provision without imposing an additional burden on residents' budgets. The city residents, on the other hand, are primarily focused on maximizing their wellbeing. They may, for example, enhance this by buying a car for their household or investing in their children's education. They may also be farsighted and prepare themselves for water-related problems and invest in water filters or health insurance in advance [15].

Although this may seem easy in theory, the simulation is complicated by a number of particularities that follow real-world constraints. Chief among these is communication, which is deliberately hampered by bureaucratic procedures. Thus, for most of the simulation, any contact between the government and the community relies on the governmental willingness to create an avenue for discussion [15]. An especially profound role is played by a journalist who acts as a mediator between the officials and the public. She can color this information sharing to escalate conflicts and undermine the government authority, to which the public can respond by refusing to pay fees or taxes and by protesting.

At the center of the simulation is the issue of trust. The governmental roles control the potential for harm in the game, which is primarily aimed at the community. Thus, the actions of government are directly connected to outcomes for the public, but the mechanism of these effects is deliberately obscured. Governmental actors, although deliberately placed at a slight

disadvantage, are given sufficient tools and resources to effectively manage the water infrastructure system but must work together to share this information and with the public to understand the effects of their actions and public priorities. Importantly, this creates a second trust relationship in which the government must come to trust the community enough to allow them to be active partners in the management process. As a result, the game dynamics create an interdependent relationship in which actors within the government and the representatives of government and the public need each other but in which violations of the trust that could facilitate those relationships are likely [15].

Unlike entertainment games, *P.I.P.E.S* (and other social simulations as well) are predominantly focused on cooperative or collaborative interactions rather than rivalry. At at the end of each round, each participant completes a survey, in which they report how trustworthy they feel other players are, how much they feel they need each other to be successful in the simulation, and how high their confidence is in the reliability and quality of the water [15]. These surveys serve two purposes. First, they prime participants to think specifically about their relationships and encourage creative solutions for improving those they feel are important. Second, however, if reported in real time, they provide an opportunity to visualize the relationships within the simulation and to identify the conditions under which effective management is most likely.

Participants of the *P.I.P.E.S* simulation often discuss the role the game played in helping them understand the importance of these general relationships and especially of perspective taking. For example, people playing the government part are often surprised at the difficulty of the role, and for some, the game was the first time they were able to empathize with the individuals who actually serve in these roles in real life. They often admit that the game helped them to realize how difficult it is to satisfy all of the competing issues and make decisions in contexts that are limited by time and budget. Many also discussed the effect of the game on their interactions with their fellow participants with whom they had to work to achieve both the success in their role and the success for the whole community.

Bouwen and Taillieu [6] describe such a process of "gather[ing] the pieces" to produce a shared vision of a problem as *social learning.* This shared vision or common goal is not present from the beginning of the multi-party collaboration; rather, it emerges during the process of interaction between actors [20]. Upon entering into a collaborative problem (in this case, urban water infrastructure management), different people wish to address the situation, but at the same time, each of them has their own way of understanding it and may be convinced that theirs is the only perspective possible. Relying on their particular relevant interest and expert knowledge, they are reluctant to notice, understand and appreciate the variety of inputs offered by other actors and accommodate them to form a shared understanding. If they do not find a common

language, however, they will not be able to get to the core of the problem and organize themselves to jointly address it.

The outcomes of social learning may be both technical (e.g. more sustainable infrastructure solutions) and relational/normative, such as a sense of ownership of solutions by different actors, empowerment, and motivation to act, and self-governing capacities [20]. With its focus on encouraging players to identify and then bridge gaps among themselves rather than encouraging them to compete or "defeat" opponents, *P.I.P.E.S* constitutes a great sandbox for learning especially about relational aspects of collaborative water infrastructure management (in this case, about the importance of mutual trust). Instead of spurring participants to fight against each other, it helps them look for common interests that go beyond their individual agendas and goals. By sharing new problem perspectives and different kinds of knowledge and expertise, players can observe, understand or even inspire each other to develop new mindsets and modify their behaviors towards a common urban water infrastructure management.

Discussion and Conclusions

This paper discusses the potential of *social simulations* in addressing issues related to urban sustainability. By presenting three recent applications of social simulations focused on different aspects of urban sustainability, we attempted to highlight specific features of these participatory activities that may add to successful sustainability learning and trigger positive behavioral change. Social simulations discussed here were *Bengaluru Quest,* which simulates collective policy-making in "the city of burning lakes," the *Sustainable Urban Heating Simulation (SUHS),* which encourages players to look for optimal urban heating solutions and reduce CO2 emissions, and the *Public Infrastructure Participatory Engagement Simulation (P.I.P.E.S.),* which simulates relationships among city officials and residents regarding water infrastructure management.

It stems from the applications described that, complying with effective sustainability learning determined by the United Nations, and engaging wide audiences in discussions on sustainability in urban contexts, social simulations may be successfully used to model and inspire positive behaviors towards increased urban sustainability.

First of all, by offering exposure to the interactive environment, social simulations engage players cognitively, perceptually and emotionally in urban sustainability-related challenges. Rather than analyzing facts from an outsider's perspective, players are fully immersed in selected urban sustainability challenges and actively use their creativity and skills to address them. This experiential sensory exposure helps them identify with their simulation-specific roles and take full control of and responsibility for their actions. As a result, it enables more participatory and personalized learning as players – who have the opportunity to learn by doing – exert control over the narration. Consequently, their sense of agency may be

developed, empowering them to recognize their individual and collective responsibilities for taking action towards increased urban sustainability.

Furthermore, by creating room for observing cause-effect relationships, social simulations offer ways for *double loop learning*, encouraging players to draw conclusions from their failures and successes, take corrective action, verify ineffective mental models and formulate new, more adequate strategies towards urban sustainability. Experimenting with different options and solutions in the safe environment of a simulation, players may materialize different sustainability scenarios without leaving the present. They thus learn to overcome the fear of the unknown and use their imagination to discover more original and innovative solutions aimed at improving the quality of life in city areas. This seems especially important in urban sustainability context, as many innovative solutions entail potential trade-offs and unexpected consequences.

Finally, by offering a collaborative experience and employing role-playing, social simulations are a great sandbox for learning especially about relational aspects of multi-party collaboration. Engagement in social simulations fosters empathy and perspective taking that are considered necessary to bridge gaps between different actors, develop mutual trust, build consensus and learn to coordinate joint action directed towards a shared goal (in this case, towards increased urban sustainability). It is especially important in the context of multi-stakeholder complex issues, such as urban sustainability, which involve as diverse groups of actors as public authorities, engineers, architects, planners, transport managers, activists or citizens, whose needs and priorities often overlap or exclude each other.

These insights gained through recent applications of social simulation outlined in the paper constitute an essential first step in researching their potential to foster learning and behavioral change in urban sustainability contexts. In our future work, we plan to delve further into the actual effectiveness of social simulations, developing evaluation instruments that will enable us to collect quantitative and qualitative data from the players. Based on the findings, more detailed research will be conducted to determine these unique features of social simulations that distinguish them from other learning transformative experiences (such as, stories, games, scenario developing, etc.) and that make them adequate tools to inspire social change.

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