# Exploring the Role of Interactive Computer Simulations in Public Administration Education

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**Abstract**
Preparing public administration students for complex challenges that involve high uncertainty, stakeholder interdependencies, policy resistance, and slow feedback cycles presents unique challenges for educators. Those in the field of public administration and public policy can broaden their educational toolbox by embracing new technologies for educating future public administration practitioners. This research demonstrates that interactive computer simulations provide dynamic contexts and creative learning environments for students to individually and collectively apply systems

thinking in information-rich environments with instant feedback channels. Across a series of exploratory studies using an interactive simulation focused on water uncertainty and policy options, this research has consistently found strong learning outcomes. The findings showed that students were able to quickly grasp the complexity associated with interdependent stakeholders with divergent interests, uncertain future conditions, and policy options that reflect competing values. However, this research also discovered some unintended consequences. Using interaction simulations may limit the scope of deliberation topics to only those that were highlighted by the simulation. Thus the research concludes with a discussion of some ethical concerns related to the use of computer simulations as part of an educational exercise.[1]

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Public administration is both theoretically grounded and practice oriented (Lynn, 1996; Shafritz, Hyde, & Parkes, 2003). Contemporary public administration faces a myriad of new challenges presented by globalization, rapid urbanization, scarcity of natural resources, and the accelerating information deluge. Most management challenges and policy problems involve intertwined interests and high complexity. Addressing these challenges requires collaborative efforts from multiple non-state stakeholders (Ansell & Gash, 2007). This ever-changing environment calls for effective teaching tools and pedagogy that constantly promotes quality teaching and learning approaches that prepare public administration practitioners to successfully navigate these existing and other unforeseen challenges.

The environment for education institutions has similarly changed. Rapid advances in information technology have transformed the way students retrieve and exchange information, communicate with one another and their instructors, and, more important, learn skills and build knowledge (Davidson & Coldberg, 2009). Thus, to adapt to the new ways of student learning, public administration educators should regularly explore innovative tools and approaches to fully exploit the potential of IT tools for public administration education.

One such tool and approach for public administration education is the use of interactive computer simulations. Interactive computer simulations can dynamically represent social structure and systems (Kriz, 2003). Computer simulations have shown promise in social science education and research (Axelrod, 1997; Garson, 1994, 2009; Gilbert, 1999; Gilbert & Tioitzsch, 2005; Page & Miller, 2007; Schelling, 1981) and have demonstrated the potential to empower students and encourage their deliberation. For educational purposes, interactive computer simulations provide an "interactive learning environment" in which students can apply what they have just learned into dynamic simulated scenarios, receive instant feedback, reflect on what can be

improved upon through trial and error, and explore the outcome of alternative "what-if" management practices and policy options (Kriz, 2003, p. 505). When the real-world management or policy context does not allow students to directly experience the situational richness, simulation environments allow students to interact with the key factors and to explore the impacts in a simulated policy context. In short, interactive computer simulation provides a promising platform for both education and knowledge building in public administration.

Within public administration practices, computer simulations are gaining traction. For instance, computer simulations have been used in helping to understand and improve traffic management (Kane, 1999), emergency management (Barrett et al., 2011; Desouza & Lin, 2011), environmental management (Learmonth Sr., et al., 2011), urban planning (Borning, Waddell, & Forster, 2007), interagency collaboration (Bardach, 2001), and public service delivery (Johnston, Hicks, Nan, & Auer, 2010). Computer simulations can help prepare public administrators to address these complex challenges that involve high uncertainty, stakeholder interdependencies, policy resistance, and slow feedback cycles. Yet there remain few systematic discussions in mainstream policy or management journals on using computer simulations for public administration practice and education. With the regular improvements to the technology and design of interactive computer simulations, regular research is needed to explore the current potential of computer simulations for public administration.

This paper examines how computer simulations can serve as teaching tools that engage students in collaborative learning and deliberation activities. First, this paper argues that the field of public administration should continually promote creative learning environments and develop new lenses that can help address old management problems and explore new research territory. Next, this paper explains the way in which interactive computer simulations can serve as creative learning platforms that engage students in an interactive and intuitive way of learning. Then, data from two exploratory case studies are analyzed, in which an interactive computer simulation of water supply and demand is used to demonstrate how such simulations can allow students to interact directly with the simulated policy scenarios, receive instant feedback, and jointly explore what-if management situations with other students. Evidence has been found for the simulation's effectiveness in facilitating learning and encouraging participants to use computer-simulated scenarios to enrich their deliberative experience on complex issues and to cultivate their collaborative capacity for solving common challenges. In addition, findings from these two studies suggested unanticipated ethical concerns regarding the ability of simulations to steer conversations and limit discussions of alternatives. This paper concludes by discussing the implications of the case study results and outlining future research on using interactive computer simulations for educational purposes in public administration.

## Reexamining Old Problems and Exploring New Research Territory

A big question in public administration and public policy programs has been identifying and implementing effective teaching approaches, strategies, modules, and delivery mechanisms so as to bridge the gap between theory and practice, attract talented individuals to commit to public service, and provide needed job skills and knowledge (Denhardt, 2001). Facing complex challenges that involve high uncertainty and interdependency with slow or absent feedback, public administrators need to build new knowledge and develop new management skills in the digital era. The current developments toward collaborative governance have intensified and expanded this debate (Posner, 2009). Public administration and public policy education programs need to cover the traditional management topics and skills such as leadership, human resources management, and budgeting and finance; they also need to address new topics such as collaborative governance and network management and to enable students to develop new management skills such as negotiation, bargaining, and contract management (Posner, 2009).

### New Assumptions and Perspectives

Interactive computer simulations can provide new perspectives on a large number of ongoing and emerging debates in both public administration and public policy (Ryan, 2000). For instance, despite the harsh critiques of the "rationality" assumption of human behavior (Simon, 1978), quantitative methods, with origins in traditional economics and belief in rationality, remain the predominant methods taught in American public policy and administration programs (Morçöl & Ivanova, 2010). The dominant economic analysis in public administration and public policy fails to capture the dynamics of human behavior and the complexity of social systems because the economic models still heavily rely on "tractable mathematical forms" (Kane, 1999, p. 523). It is difficult, if not impossible, to use fixed mathematical functions to explain or predict human behavior since "people learn and adapt and change" (Kane, 1999, p. 523).

Computer simulations, unlike conventional statistical analysis, often build on complexity theory (Axelrod, 1997) and take the perspectives of complex adaptive systems toward social systems. Computer simulations are "smaller, less detailed, less complex" representations of real-world structures and systems (Gilbert & Tioitzsch, 2005, p. 2). Assuming that individuals, groups, and organizations are adaptive agents, computer simulations allow us to study how complex behaviors, social processes, and interactions emerge from the activities that follow the simple rules observed in reality (Gilbert, 1999) . The focus of the simulation is not on the static status or outcomes, but on the emergence of dynamics and interactions at the micro and macro levels of the systems (Axelrod, 1997; Gilbert & Tioitzsch, 2005). Computer simulations allow researchers

to change the conditions by setting the parameters at different values and execute the simulation many times to test the effects of different settings and assumptions (Gilbert, 2005).

Additionally, conventional economic approaches and statistical models usually assume that the relationships between variables take on fixed and mostly linear patterns (Gilbert & Tioitzsch, 2005, pp. 16–17). In reality, the relationship between variables is dynamic and mostly nonlinear. Computer simulation approaches challenge the traditional assumptions that individuals are rational actors and that there are static, linear relationships among diverse agents within social systems (Gilbert & Tioitzsch, 2005). The dynamic simulation modeling of complex social phenomena enables researchers and educators to apply new frameworks to explore a wide array of social problems (Gilbert & Tioitzsch, 2005).

**New Analysis Tools**

Computer simulations, such as agent-based modeling and system dynamics modeling (Gilbert, 2005), are tools for examining conventional public administration problems and exploring new questions and territories (Garson, 2009). For instance, Kim, Johnston, and Kang proposed "a computational approach to managing performance dynamics in networked governance systems" (2011, p. 580). They criticized the conventional positivist-reductionist approach to performance management, saying that it conducts *ex post* performance evaluation and focuses on finding the best solution through managing resources, exploiting technical innovation, and improving internal management. Instead, they argued for a "complex adaptive systems" view of performance in "networked governance systems." They suggested that computer simulation modeling of performance focuses on "*ex ante* conditions and dynamic tensions among multiple stakeholders" (Kim et al., 2011, p. 580). To understand how management decisions affect the performance of collaborative governance, they proposed that a simulation model can be built to represent a dynamic performance system to test the performance outcomes of different conditions (Kim et al., 2011). Researchers therefore can observe the individual agent's behavior, aggregate performance outcomes, and understand the processes that led to those outcomes (Kim et al., 2011). Using agent-based modeling, each stakeholder can be modeled as an agent with diverse attributes and interaction rules that interacts with other agents and the environment and adapts their behavior accordingly (Gilbert & Tioitzsch, 2005). Additionally, computer simulations make it feasible to explore the problems that are difficult to observe and analyze in real-world scenarios (Gilbert & Tioitzsch, 2005; Kim et al., 2011). Gilbert (2005) noted that one advantage of simulation lies in its ability to include spatial location in the analysis of many social problems. In short, the use of computer simulations has developed enough to explore many questions that are not particularly well suited to other methods.

## Simulations as Creative Learning Platforms

Advances in information technology have spurred transformative changes in how students interact and communicate with each other as well as search and exchange information. The past few decades have seen dramatic changes in the way students learn. Students use the Internet to search for information, social networking sites to connect with classmates, and social media to collaborate on class projects (Ellison, Steinfield, & Lampe, 2007). Hence, public administration educators need to go beyond innovating conventional pedagogy; they also need to actively explore more interactive and engaging pedagogy to connect with students, inspiring them to conduct research and engage in public services.

Among the innovative teaching modes, computer simulations demonstrate great potential for providing creative learning environments. Since the 1990s, a number of successful computer simulations have been used for training in the field of public policy and management practices (Sawyer, 2002): SimCity (a city-building simulation game), SimHealthcare (a simulation of the U.S. health care system), and Virtual U (a simulation for the operation higher education). Syracuse University holds an annual simulation competition for public administration education at the Program for the Advancement of Research on Conflict and Collaboration (E-PRACC). These simulations encourage students to develop team skills, hold stakeholder meetings (Alexander, 2009; Brazil & Teram, 2009), practice their negotiation skills, reach policy consensus (George, 2010), conduct conflict analysis (Ebner & Efron, 2010), and understand network structure (Bryer & Stewart, 2008; Davis & Varda, 2010; Varda, 2008). Yet, most of the simulations do not use computers, but instead use traditional methods, such as detailed case descriptions and role playing, to mimic the real-world scenarios and encourage student interactions.

A large number of studies discuss the designs and applications of computer simulation in other disciplines, especially in game design and instructional information technology (e.g., Aldrich, 2009; Reeves & Read, 2009; Schank, 2002). Aldrich (2009) assumed that, compared with "traditional linear media" such as "books, movies, and lectures," which focus on the accumulation of facts and teaching learning-to-know, computer simulation focuses on "practiceable" and "active content of learning-to-do" (p. xxxi). He noted that linear contents fail to help people develop skills such as leadership and "create an accurate representation of time and space" (p. xxxi). Policy games help participants to jointly explore the possibility space, build up a shared understanding of key concepts, and search creatively for solutions (Haug, Hutema, & Wenzler, 2011). In a study of water sustainability, Dray, Perez, Le Page, and Aquino (2007) used simulation games as a tool to provide relevant information and facilitate dialogues among the local stakeholders. They found that with the help of simulations, participants distanced themselves from extreme views

and adopted a more flexible approach toward future negotiations. Similarly, Dionnet, Kuper, Hammani, and Garin (2008) used role-playing games as a form of simulation tool to raise awareness among farmers about the scope and contents of a joint irrigation project. They suggested that simulations can encourage collective decision making because farmers were deeply involved in discussing each issue and reached agreements on joint irrigation at the end of the process (Dionnet et al., 2008). Jarmon, Keating, and Toprac (2008) described a "university-sponsored, experiential-based simulation" as a medium to increase public awareness and influence diverse stakeholder's perspectives in participatory learning environments (p. 168). Jarmon, Keating, and Toprac (2008) found that simulation generated intensive communication among participants and helped them develop a better understanding of others' roles. Reeves and Read (2009) argued that sophisticated, well-designed simulation games can offer great ideas and lessons on how to motivate workers with tedious jobs and get them more engaged in work. They also anticipated that game environments would become one of the regular work environments and an important business platform (Reeves & Read, 2009). These disparate examples of computer simulations have demonstrated great potential as a creative learning platform to engage students in a more interactive and intuitive way of learning. As the problem contexts are more systematically understood, computer simulations have an increasing relevance to standard public administration pedagogy.

## Case Studies: A Policy Deliberation Exercise Using Computer Simulations

The following section uses computer simulations of water supply and demand as a case study. This case study illustrates how a computer simulation in general and certain features in particular can be used to teach the complexity of management challenges, policy scenarios, and social systems and processes as well as to engage students in collaborative learning and deliberation activities.

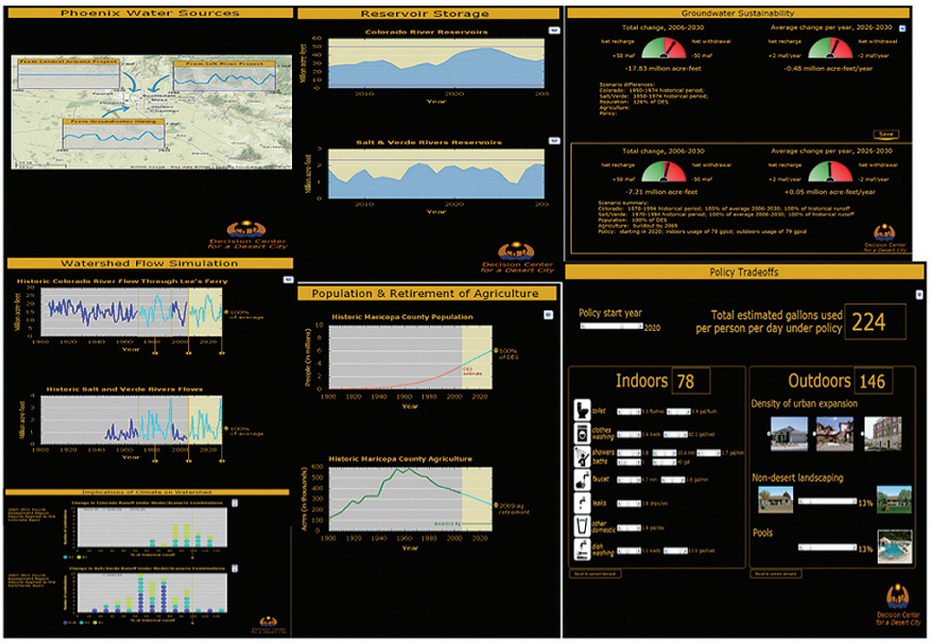
### WaterSim: A Computer Simulation of Water Supply and Demand in Phoenix

Two exploratory studies were conducted in the spring of 2010 and 2011 in the Decision Theater at Arizona State University (ASU). The ASU Decision Theater has a unique site known as the "Drum," which is a room that can seat up to 25 participants and contains a 260-degree, seven-screen display. The facility is equipped with a real-time human-computer interface, interactive group support systems, networked laptops, and high-fidelity video-recording equipment capable of producing a shared dynamic display of scenarios. During the study, students directly interacted with dynamic computer-simulated scenarios, received instant feedback, and evaluated alternative policy options.

This study used a simulation called WaterSim, developed by the Decision Center for a Desert City at Arizona State University. WaterSim is a computer

simulation of water supply and demand for the Phoenix, Arizona, metropolitan area (see Figure 1). WaterSim is an interactive simulation model designed to help a wide variety of stakeholders deliberate on and anticipate water challenges in the Phoenix metropolitan area under conditions of uncertainty. WaterSim allows stakeholders to adjust parameters to explore different scenarios of climate change, population increase, and agricultural water use to see their impacts on water sustainability at various times. It also includes a policy interface that enables users to explore alternative policy choices on indoor and outdoor water use and receive instant feedback on the environmental impacts of their choices.

*Figure 1.*
WaterSim's Seven-Screen Display Compressed Into One Image




*Source.* Decision Theater for a Desert City, Arizona State University.

**Case One: Learning Through Interactive Simulations**

We invited students to interact with WaterSim and each other, and to deliberate on water issues in Phoenix. Before interacting with WaterSim, students were tested on their knowledge of regional water sources, water availability, and factors influencing water sustainability. Then they were asked to interact with WaterSim and deliberate on water problems, goals, and plans to address these problems.

Every group received these instructions after being introduced to WaterSim:

> Water issues are a problem in Phoenix. How would you deal with those water problems? This is a setting where you can play out and test your decisions. Discuss among yourselves and then let me know what adjustments you would like me to make to the settings in the simulation. Information about WaterSim is also available in your information packet—if you have questions, please start there. If you don't find an answer, feel free to ask me. We'll work on this task for 20–25 minutes.
>
> At the end of that time, please write down your goals for addressing the water problems in Phoenix and your plan for achieving those goals. When you make changes to the settings, please think about how those changes affect other aspects of the simulation. Here is the paper on which you should write your goals and plans.

While discussing the goals and plans for addressing water problems in Phoenix, participants were asked to adjust the various inputs to WaterSim and to gauge the effects of those adjustments on water sustainability.

This exploratory study was conducted during the spring semester of 2010. A total of 126 students, mostly undergraduates, participated in the study at the ASU Decision Theater. We used a mixed sampling method to recruit students, including sending out e-mails, handing out flyers at the campus cafeteria, and making multiple in-class announcements in large-size undergraduate classes. These students are from various disciplines and diverse ethnicities.

**Case Two: Learning About Limited Resource Allocation Through Interactive Simulations.**

Thirty-six graduate students studying public management, public policy, and business management participated in the second study. Students were first given 100 collective attention units and asked how to allocate them to different categories of challenges in society (crime, economy, health care, sustainability, and education) and how to split a separate 100 collective attention points into subcategories related to sustainability (population growth, intergovernmental cooperation, technology, urban planning, and personal responsibility). These collective units were introduced as the hypothetical investment resources that each participant can allocate in society as if they were policy makers needing to set policy priorities. Next, students were introduced to WaterSim. While interacting with WaterSim, they were asked to discuss with each other the challenges associated with water facing the region, factors that should be considered related to the water issues, policy strategies, and ways to evaluate if their proposal could be seen as successful. After the WaterSim activity, students were again asked to allocate collective attention units using the same categories.

The second case study was conducted during the spring semester of 2011 at the ASU Decision Theater. This study was built into the class curriculum, and students participated in the study as part of a regular class session. Through these studies, results were found related to learning, collective behavior, and relative perceptions about community priorities.

## Results

The following section reports the findings from the two exploratory studies on students' learning outcomes and perception change after interacting with the computer simulations of water supply and demand for the Phoenix metropolitan area. This section also discusses ethical concerns identified by the study in applying computer simulations.

### Learning Outcomes

Water sustainability is a complex management issue that requires public administrators to grapple with the multifaceted aspects of water management. Public administrators need to understand existing water sources and status of water reservoirs, impacts of uncertain climate changes, population growth, economic development, agricultural development, indoor and outdoor water use, urban management, and so on. Hence, teaching complicated management topics such as water sustainability is challenging because the concept is profound and many intertwined factors must be considered. With a computer simulation, public admini-stration students can observe the impacts of multiple factors by exploring the simulated vivid scenarios and testing the dynamic relationships between these factors.

Results from the first exploratory study suggest that WaterSim is an effective tool for teaching students about the diverse, intertwined aspects of water sustainability. Compared with students' knowledge about water issues in Phoenix before their interaction with WaterSim, students' knowledge increase was statistically significant. Due to violation of normality and equal variances, we conducted Friedman's test to compare students' knowledge about water issues in Phoenix before and after students interacted with the simulation. Students' aggregate knowledge score on average increased from 3.35 to 4.64 on a scale of 1 to 5. Friedman's test shows that the difference was significant ($\chi^2$ (1) = 52.1, $p < 0.001$). Students achieved a quick comprehension of the complexity of water problems in Phoenix. The Kendall's coefficient of concordance was 0.41, indicating strong differences in students' knowledge scores.

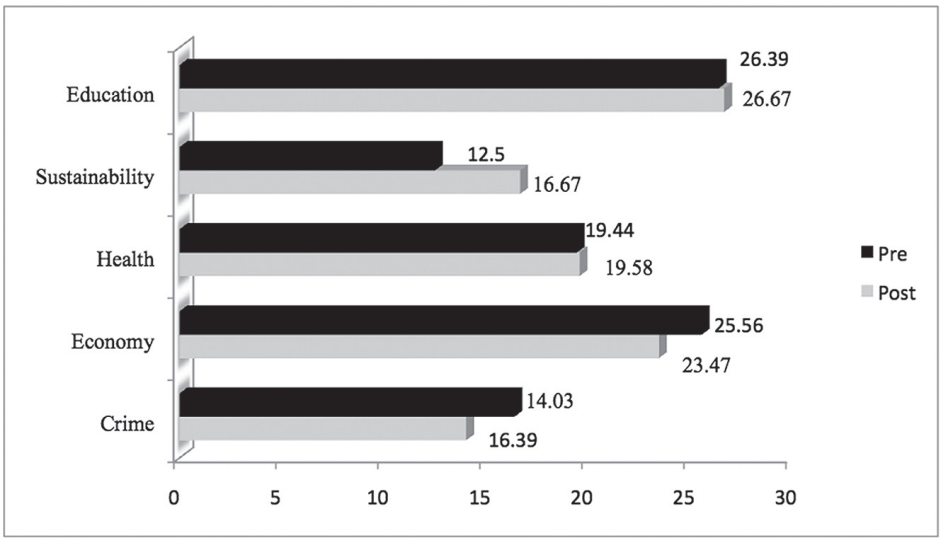
### Perception Change

Perception precedes action. Therefore, it is important to examine the potential influence of the application of computer simulations on people's perception about water sustainability. Due to the vivid and dynamic way of displaying information, interactive computer simulations can influence the formation of perception in a pervasive manner. With thoughtful designs and applications, this attribute can be strength of using computer simulations for public administration education. In the meantime, it raises ethical concerns about the unintended outcomes of using computer simulations.

Results from the second study show that students' interactions with WaterSim influence their perception about sustainability in a quick and persuasive manner. In the before and after test, separated by less than 30 minutes of interactions with the simulation and other students, students were asked to assign a total of 100 collective attention units to five categories of priority problems of society (i.e., crime, economy, health care, sustainability, and education). This is a general approximation to spending political capital or setting a policy agenda. Under the category of sustainability, students were also asked to assign 100 collective attention units to five aspects of sustainability (population, intergovernmental cooperation, technology, urban planning, and personal responsibility).

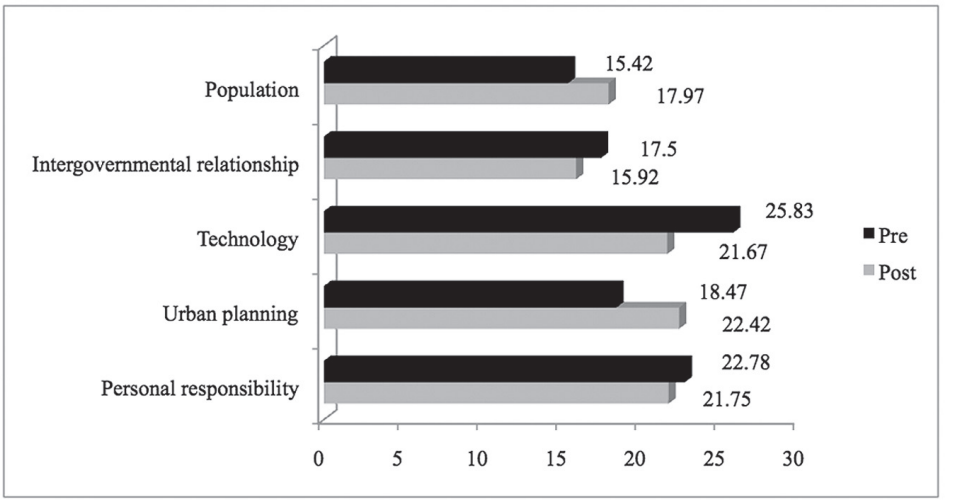
After the interactions, students on average increased the attention budgeted to the sustainability category by 33% (from 12.5 to 16.67; see Figure 2). This difference is statistically significant ($p = 0.003$). This is an interesting, yet expected, finding because among the five priority problems, only sustainability was reflected in the model. Because this study is designed to have a finite attention budget, an increased focus on sustainability required a decreased focused on another social problem. Surprisingly, under the current backdrop of a slowly recovering economy, students reduced the collective attention from 25.56 to 23.47, a reduction of 8.14%, which is also statistically significant ($p = 0.034$). Another interesting finding is that crime, an enduring social problem, received even less attention, decreasing from 16.39 to 14.03. The relative reduction of 14.40% is statistically significant ($p = 0.015$).

*Figure 2.*
A Comparison of Attention Units to Social Problems Before and After the Interaction With WaterSim



In regard to the subcategories of sustainability, urban planning also received higher collective attention: an increase of 21.33% more attention (from 18.47 to 22.42, $p = 0.022$) (see Figure 3). This result is consistent with one focus emphasized in the model that noted different urban density could greatly affect water sustainability. In addition, technology, an option not available to explore in the model, received less attention, resulting in a decrease of 16.14% (from 25.83 to 21.67, $p = 0.022$). In short, peoples' perception about how to allocate collective attention to social challenges significantly changed right after the interaction with the model and in a manner that is suggested by the model.

*Figure 3.*
A Comparison of Attention Units to Five Categories of Sustainability Issues Before and After the Interaction With WaterSim




Our findings suggest that the availability of an outcome measure influenced the scope of deliberations. For instance, the simulation in this case focused on the long-term use of a scarce resource, and the outcome measure showed how a set of policies and environmental conditions create either a resource surplus or deficit. Before using the simulation, people were asked to brainstorm and write down challenges and solutions related to that scarce resource; they created solutions that included environmental, economic, and community indicators. After using the resource model, they were again asked to brainstorm and write down challenges and solutions related to scare resources. In the brainstorming session held before participants interacted with the model, the problem was framed broadly to include values such as quality of life and economic viability of the region. Solutions also included market strategies and technological innovation as well as emphasizing personal responsibility. The problems and recommendations in the post-session questionnaire became solely focused on avoiding a resource

deficit, the articulation of success was dominated by the metrics of the model, and solutions were primarily ones that were supported by options in the model. Students narrowed their scope of deliberations. This response showed that the presence of available or understandable evidence within the model shaped the conversation to the exclusion of legitimate issues raised before students had interacted with the model. Narrowing the scope unintentionally reduced the multiple dimensionalities of the management challenge and decreased the possibility of proposing alternative approaches. On one hand, this finding demonstrates both the potential of using computer-simulated scenarios to influence the way students think in a very efficient manner; on the other hand, it calls for more consideration when we apply simulation models in classrooms.

**Ethical Considerations in Applying Simulations**

Another caveat in developing and using simulation models is incorporating ethical considerations. Ethics is a crucial topic in public administration research and praxis (Svara, 2007); however, ethics in simulation modeling has received little attention. Simulation is a useful tool for social science research as well as a novel medium for education and communicating with policy makers. Recent decades have seen an increasing use of simulation in many classrooms, libraries, and museums (Binstadt, et al., 2007). Various computer simulations have been used to inspire students' interests, encourage participation, and enhance learning due to the real-time interactions and intuitive manner of information presentation in simulations. Compared with the large number of studies examining the effectiveness of simulation in improving learning outcomes, the study on the unintentional outcomes of using simulation has received little attention.

In this study, the simulation demonstrated its power in shaping peoples' conversational directions as well as their perceptions and stated preferences. Simulation models may influence peoples' perceptions in ways that were unintended and unnoticed by the model builders. In other words, simulations may be used to promote certain ways of thinking without the users being conscious of its biases. Hence, it is necessary for model builders to not only think about the opportunities of using simulations but also consider what potential biases and unintentional outcomes the simulation may bring about. This study showed that simulations change peoples' perceptions in a quick and consistent manner by shifting their attention to measures and mechanisms that are of interest to the modelers. Hence, the modelers need to make sure that the perspectives and interests of the stakeholders, especially those of the less advantaged stakeholder, can be considered. We recommend that the simulation model needs to stand on well-tested assumptions and incorporate diverse aspects of the real-world scenarios. The simulation model should be vetted by the stakeholders who are affected by the potential application of the model. Ethics, currently an afterthought in modeling, should be a pervasive consideration in developing and using simulations.

## Limitations

These findings come from two exploratory studies of using computer simulations for engaging students in learning and deliberating on complex management scenarios in an interactive manner. This study does not claim that computer simulations are superior to other teaching tools, and the study design is not intended to make such a claim. Instead, these two exploratory case studies are early attempts to use computer simulations in educating students about the complexity of management scenarios and providing students with an interactive learning environment in which they can directly interact with diverse what-if scenarios, receive instant feedback, and develop a quick understanding of the management issue.

There are other limitations of this study. These two exploratory studies involve a relatively small number of student participants. Our next study will include more students with more diverse backgrounds. A comparable simulation design will be incorporated into the study to investigate what configurations of simulations are more effective in facilitating students' collaborative learning and deliberation.

## Conclusion

Computer simulations have received increasing attention in a wide range of management and policy domains, although the traditional approaches and tools that adopt the rationality assumptions and focus on static, linear relationships remain predominant. Most mainstream public administration journals present relatively few discussions on interactive computer simulations. Hence, this study calls for more attention to be directed at the great potential of computer simulations as tools for public administration education.

This study first identifies a set of complex challenges facing public administration research and education, such as the high level of environmental uncertainty and intertwined relationships among diverse actors in public service delivery. Current public administration approaches may struggle to address these challenges. Then, this study indicates that computer simulations can provide dynamic contexts for public administration research and education and serve as new tools for reexamining the conventional public administration problems. Furthermore, interactive computer simulations can act as platforms for engaging students in deliberating on real-world policy problems and exploring what-if scenarios in a group setting with quick feedback channels, hence helping students understand the complexity of collective decision making.

This study presents a specific interactive computer simulation that we have used in our courses as a platform for students to explore a complex management topic—water sustainability—and develop an understanding of the intertwined relationships among various factors in water management. Through two exploratory case studies, this study suggests that, after interacting with computer simulations (WaterSim in this study), students quickly were able to grasp the complex challenges associated with interdependent stakeholders, uncertain figures, and policy options that reflect competing values. Students' perception about sustainability and resource allocation also changed greatly. Participants'

perception change mirrored the desired outcome of the simulation. In addition, this study found an unintended narrowing of the deliberation options. Hence, this study calls for attention to the ethical considerations in using simulations, which have received less attention in previous studies.

While this study was conducted using WaterSim in the Decision Theater at Arizona State University, diverse types of computer simulations can run on personal laptops and be accessed easily through the Internet. With the decreasing cost of developing computer simulations, we anticipate that this type of simulation will be more commonly used in public administration research and education. These simulations can be used in public administration classes to engage students in exploring complex management scenarios, facilitating students' deliberation activities, and encouraging student interactions. This study strengthens the justification for using simulation-based scenarios to address new educational challenges while providing evidence of its effectiveness. The study is also an early step toward systematically understanding the potential and consequences of using such simulation-based scenarios in public administration education.

## Footnote

1 This material is based upon work supported by the National Science Foundation under award numbers SES-0951366 and SES-0345945, Decision Center for a Desert City (DCDC). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation (NSF).

## References

Alexander, R. (2009). Addressing ELCA: An exercise in designing and facilitating stakeholder processes Retrieved from http://www.maxwell.syr.edu/uploadedFiles/parcc/eparcc/simulations/ALEXANDER-Case.pdf

Aldrich, C. (2009). *The complete guide to simulations and serious games: How the most valuable content will be created in the age beyond Gutenberg to Google*. San Francisco: Pfeiffer.

Ansell, C., & Gash, A. (2007). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory, 18*(4), 543–571. doi: 10.1093/jopart/mum032

Axelrod, R. (1997). Advancing the art of simulation in the social sciences. *Complexity, 3*(2), 16–22.

Bardach, E. (2001). Developmental dynamics: Interagency collaboration as an emergent phenomenon. *Journal of Public Administration Research and Theory, 11*(2), 149–164.

Barrett, C. L., Eubank, S., Marathe, A., Marathe, M. V., Pan, Z., et al. (2011). Information integration to support model-based policy informatics. *Innovation Journal, 16*(1), Article 2 (a special issue on policy informatics).

Binstadt, E., Walls, R. M., White, B. A., Nadel, E. S., Takayesu, et al. (2007). A comprehensive medical simulation education curriculum for emergency medicine residents. *Annals of Emergency Medicine, 49*(4), 495–504.

Borning, A., Waddell, P., & Forster, R. (2007). UrbanSim: Using simulation to inform public deliberation and decision-making. In H. Chen, L. Brandt, V. Gregg, R. Traunmüller, S. S. Dawes, et al. (Eds.), *Digital government: E-government research, case studies, and implementation* (pp. 439–466). New York: Springer.

Brazil, M., & Teram, E. (2009). Collaboration gone awry: A struggle for power and control over service delivery in the non-profit sector. A simulation—Exploring perspectives of individual collaborating organizations. Retrieved from http://www.maxwell.syr.edu/uploadedFiles/parcc/eparcc/simulations/Ketcham%20edit%20BRAZIL-TERAM-Simulation.pdf

Bryer, T., & Stewart, K. (2008). Developing a young professions network for the Arts: Teaching notes. Retrieved from http://www.maxwell.syr.edu/uploadedFiles/parcc/eparcc/simulations/Bryer-Stewart%20Introduction.pdf

Davidson, C. N., & Coldberg, D. T. (2009). *The future of learning institutions in a digital age*. Cambridge, MA: The John D. and Catherine T. MacArthur Foundation.

Davis, M., & Varda, D. (2010). Mapping network structure in complex community collaborators: A teaching simulation. Retrieved from http://www.maxwell.syr.edu/uploadedFiles/parcc/eparcc/simulations/Davis-Varda-Mapping%20Network%20Simulation%202011.pdf

Denhardt, R. B. (2001). The big questions of public administration education. *Public Administration Review, 61*(5), 526–534.

Desouza, K. C., & Lin, Y. (2011). Towards evidence-driven policy design: Complex adaptive systems and computational modeling. *The Innovation Journal: The Public Sector Innovation Journal, 16*(1), Article 7.

Dionnet, M, Kuper, M., Hammani, A., & Garin, P. (2008). Combining role-playing games and policy simulation exercises: An experience with Moroccan smallholder farmers. *Simulation and Gaming, 39*(4), 498–514.

Dray, A., Perez, P., Le Page, C., D'Aquino, P., & White, I. (2007). What wants to terminate the game? The role of vested interests and metaplayers in the ATOLLGAME experience. *Simulation and Gaming, 38*(4), 494–511.

Ebner, N., & Efron, Y. (2010). Little Golano: A simulation. Retrieved from http://www.maxwell.syr.edu/uploadedFiles/parcc/eparcc/simulations/Ebner%20Simulation%202011.pdf

Ellison, N. B., Steinfield, C., & Cliff, L. (2007). The benefits of Facebook "friends": Social capital and college students' use of online social network sites. *Journal of Computer-Mediated Communication, 12*(4), 1143–1168.

Garson, G. D. (1994). Social science computer simulation: Its history, design, and future. *Social Science Computer Review, 12*(1), 55–82.

———. (2009). Computerized simulation in the social sciences. *Simulation & Gaming, 40*(2), 267–279.

George, M. (2010). An exercise in environmental collaborative planning. Retrieved from http://www.maxwell.syr.edu/parcc/eparcc/simulations/2011_2_Simulation/

Gilbert, N. (1999). Simulation: A new way of doing science. *American Behavioral Scientist, 42*(10), 1485–1487.

Gilbert, N., & Tioitzsch, K. G. (2005). *Simulation for the social scientist* (2nd ed.). Columbus, OH: McGraw-Hill Education.

Haug, C., Huitema, D., & Wenzler, I. (2011). Learning through games? Evaluating the learning effect of a policy exercise on European climate policy. *Technological Forecasting and Social Change, 78*(6), 968–981.

Jarmon, L., Keating, E., & Toprac, P. (2008). Examining the societal impacts of nanotechnology through simulation: NANO SCENARIO. *Simulation and Gaming, 39*(2), 168–181.

Johnston, E. W., Hicks, D., Nan, N., & Auer, J. C. (2011). Managing the inclusion process in collaborative governance. *Journal of Public Administration Research and Theory, 21*(4), 699–721. doi: 10.1093/jopart/muq045

Kane, D. (1999). Computer simulations. In G. Miller & M. L. Whicker. (Eds.), *Handbook of research methods in public administration.* New York: Marcel Dekker.

Kim, Y., Johnston, E., & Kang, H. S. (2011). A computational approach to managing performance dynamics of networked governance systems. *Public Performance & Management Review, 34*(4), 580–597.

Kriz, W. C. (2003). Creating effective learning environments and learning organizations through gaming simulation design. *Simulation & Gaming, 34*(4), 495–511.

Learmonth Sr., G. P., Smith, D. E., Sherman, W., White, M. A., & Plank, J. (2011). A practical approach to the complex problem of environmental sustainability: The UVa Bay Game. *Innovation Journal: The Public Sector Innovation Journal, 16*(1), Article 4.

Lynn, L. E. (1996). *Public management as art, science, and profession.* Chatham, NJ: Chatham House Publishers.

Morçöl, G., & Ivanova, N. P. (2010). Methods taught in public policy programs: Are quantitative methods still prevalent? *Journal of Public Administration Education, 16*(2), 255–277.

Page, S. E., & Miller, J. H. (2007). *Complex adaptive systems: An introduction to computational models of social life.* Princeton, NJ: Princeton University Press.

Posner, P. (2009). A public administration education for the third-party governance era: Reclaiming leadership of the field. In R. O'Leary & L. B. Bingham (Eds.), *The collaborative public manager: New ideas for the twenty-first century* (pp. 233–254). Washington, DC: Georgetown University Press.

Reeves, B., & Read, J. L. (2009). *Total engagement: Using games and virtual worlds to change the way people work and businesses compete.* Watertown, MA: Harvard Business School Press.

Ryan, T. (2000). The role of simulation gaming in policy-making. *Systems Research and Behavioral Science, 17*(4), 359–364.

Schank, R. C. (2002). *Designing world class e-learning: How IBM, GE, Harvard Business School, and Columbia University are succeeding at e-learning.* New York: McGraw-Hill.

Schelling, T. C. (1981). *The strategy of conflict.* Cambridge, MA: Harvard University Press.

Shafritz, J. M., Hyde, A. C., & Parkes, S. J. (2003). *Classics of public administration.* Florence, KY: Wadsworth Publishing.

Simon, H. A. (1978). Rationality as process and product of thought. *American Economic Review, 68*(2), 1–16.

Svara, J. H. (Ed.). (2007). *The ethics primer for public administrators in government and nonprofit organizations.* Sudbury, MA: Jones & Bartlett Learning.

Varda, D. (2008). Strategic network management in a community collaborative: A simulation. Retrieved from http://www.maxwell.syr.edu/parcc/eparcc/simulations/2008_1_Simulation/

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