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ADDRESSING COMPLEXITY WITH PLAYABLE MODELS

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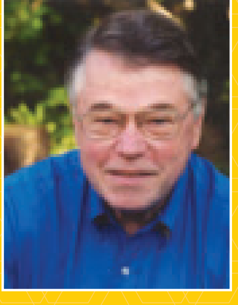

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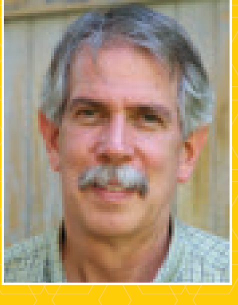


David Rejeski directs the Science and Technology Innovation Program (STIP) at the Woodrow Wilson Center. The mission of STIP is to explore the scientific and technological frontier, stimulating discovery and bringing new tools to bear on public policy challenges that emerge as science advances. STIP focuses on emerging technologies and the critical choices innovation presents to public policy. Work includes synthetic biology (www.synbioproject.org), Do-It-Yourself Biology, nanotechnology (www.nanotechproject.org), participatory technology assessment, geoengineering, additive manufacturing, and the application of video games to public policy challenges. Rejeski is a Guest Scholar at the International Institute for Applied Systems Analysis (IIASA) in Austria and a Visiting Scholar at the Environmental Law Institute. Between 1994 and 2000, he worked at the White House Council on Environmental Quality and the Office of Science and Technology on a variety of technology, R&D, and policy initiatives. Before working at the White House, he was head of the Future Studies Unit in the Environmental Protection Agency's Office of Policy, Planning and Evaluation.

Summary

The purpose of this project is to examine the nature of "complex systems," explain the difficulties involved in dealing with problems in complex systems, and explore methods of improving governance and public engagement through the use of interactive models of complex systems, or **playable models**, both in public policy and journalism. We are interested in exploring the following questions:

- In what ways is our world becoming more complex?
- What are the major barriers our governance systems face in addressing complex system problems?
- What are the primary challenges in communicating complex systems to policymakers and the public?
- How can we improve communication and public engagement processes? More specifically, is journalism up to the job?
- Could playable models – interactive models of a complex system with which people play – be useful in fostering deeper understanding of complex systems?

We undertook more than 25 structured interviews with people from a variety of backgrounds: systems analysts, experts on complexity, journalists, game designers, media specialists, literacy scholars, and people who study the policymaking process (list appended). These interviews, combined with additional research, informed this paper with a focus on how to improve public engagement and communication methods around complex systems. The following findings emerged from the project:

- Increasing interconnectivity, faster rates of change, population growth, and impacts of emerging technologies are driving the emergence of a growing number of complex systems problems. Today, for example, suspicious activities at one airport can shut down flights between countries, infectious diseases can move

thousands of miles in hours, and the bad behavior of traders at one bank can cause the entire world economy to contract.

- Policymakers and organizations that make up our democratic system of governance face a number of challenges and barriers to addressing complex systems challenges, including outmoded organizational structures and strategies, decreasing diversity, and the lack of a shared language to enable a dialogue or action around complex issues.
- The inability to engage decision-makers and the broader public around complex issues cuts across a wide variety of institutions, from government agencies to think tanks to news organizations.
- While complexity is increasing, no significant initiatives or mainstream organizations are focused on improving our ability to confront it.
- Playable models have begun to emerge as a powerful method for improving understanding of complex issues and lend themselves well to public engagement, but they are still underdeveloped and underutilized.

How Did We Get Into This Mess?

EMERGENCE OF COMPLEXITY

It is difficult to tell whether complex systems simply emerged sometime in the last century or whether our awareness of them just heightened — or both. But one can roughly pinpoint the time when the façade of technical rationality that hid complexity from our collective awareness began to crumble.

In 1972, Herbert Simon published his seminal essay questioning the theory of rational human behavior underpinning most economic theory.[1] In 1973, the concept of "wicked problems" appeared, defining a class of public policy challenges that have no definitive solutions, are often symptoms of other problems, and are difficult to solve using normal methods.[2] Daniel Bell also wrote the *Coming of Post Industrial Society* in 1973, predicting an era where the complexity of the machine age would be surpassed by the growing complexity of an interconnected "knowledge society." That same year, two political scientists, Aaron Wildavsky and Jeffery L. Pressman, published an analysis of federal social and economic development programs that were consistently undermined by the complexity of their coordination requirements, both within individual programs and between programs.[3] Five years later, economist Richard Nelson wrote a short book called *The Moon and the Ghetto*, which pointed out that the technical rationality that engineered the moon landing was not necessarily transferable to the complex social challenges that pervade our educational system.[4] And throughout the decade, the Club of Rome sponsored studies on the "world problematique," the problem of interacting global problems.[5]

So the 1970s gave us more than the Frisbee. It represented a watershed decade where there was a vague sense that the world was becoming increasingly messy, interactions more complex, solutions harder to implement, and human control of social and technological systems more tenuous. In 1979, the accident at the Three Mile Island nuclear reactor occurred and Yale sociologist Charles Perrow concluded in his classic work *Normal Accidents* that certain technological systems, such as nuclear reactors, are inherently prone to disaster because the systems are "tightly coupled" and display what he termed "interactive complexity."

Two decades later, the Organization for Economic Co-operation and Development began to talk about *emergent systemic risks* that plague financial markets, electric grids, and ecosystems.[6] More recently, policymakers learned hard lessons about the nature of systemic risks after both the New Orleans levees and Lehman Brothers collapsed. In 2007, a National Research Council report concluded: "Globalization in all its dimensions – economic, technological, cultural, environmental – is growing apace and increasing interdependence, making it all the easier for dangerous pathogens, pollutants, and technical failures to spread. Equally important, the frontiers of scientific discovery and technological innovation are expanding at breathtaking speed, confronting society with unknown (indeed, unknowable) impacts, and therefore immensely difficult choices."[7]

> "Complexity could be like the Enlightenment in the 18th century – it is a big idea."
>
> Roland Kupers

By the turn of the millennium, Cambridge University physicist Stephen Hawking asserted, "The next century will be the century of complexity." People are beginning to talk of "super wicked problems" such as climate change.[8] Some maintain we have moved beyond complexity to "hypercomplexity" or "second-order complexity," in which complex systems are embedded within other complex systems.[9] But what do we actually mean by these terms?

WHAT IS COMPLEXITY?

Gene Bellinger, the founder and host of the Systems Thinking World online discussion group, says, when asked about his work, he used to start explaining "complexity" and "systems theory" and within seconds would see the other person wanting to get out of the conversation. He finally hit on saying that his work is about "*figuring out how to solve problems in a way that they stay solved and don't lead to other problems*." That might have held his audience longer, but it dodges the difficult task of defining complexity.

Part of the reason complexity is hard to explain is that most people's intuitive sense of what is "simple" and what is "complex" is not very clear. Many things that appear complex, like an internal combustion engine, can actually be modeled through deterministic equations with a high degree of accuracy. Other things that appear simple turn out to be remarkably complex when examined closely. A small aquarium seems simple when viewed as a decoration, but is incredibly complex when viewed as a living system.

Perhaps the best place to begin is by exploring another distinction, the difference between "complicated" and "complex."[10] A smart phone is complicated and a jumbo jet is extremely complicated in the sense of having a large number of parts and performing sophisticated functions. But as complicated as such things may be, they can, in principle, be given an exact description and their behavior predicted reliably (apart from component failures). Things that are truly complex, like a cell, a brain, or an economy do not just have a large number of parts in a fixed pattern; they have intricate, constantly changing interactions between their parts. Complexity emerges as a result of the rich patterns of dynamic interaction between large numbers of elements.

All these interactions and feedback loops give complex systems very different characteristics from those of a smart phone or jumbo jet. No exact description of them is possible. Their parts alter and adapt rather than remain fixed. They are subject to sudden change and "emergence" – the development of fundamentally new characteristics. Their behavior cannot be reliably predicted and interventions in them often have consequences that are counterintuitive. They are so sensitive to initial conditions that doing the same thing twice is unlikely to produce the same outcome. Complex systems can be influenced, but they are hard to control.

WHAT IS DRIVING COMPLEXITY?

There was unanimous agreement among experts interviewed for this paper that the world is indeed becoming more complex. People we spoke with saw this as a major trend shaping the future and unlikely to reverse. These are the main factors they believe are driving complexity:

1. Interconnectedness

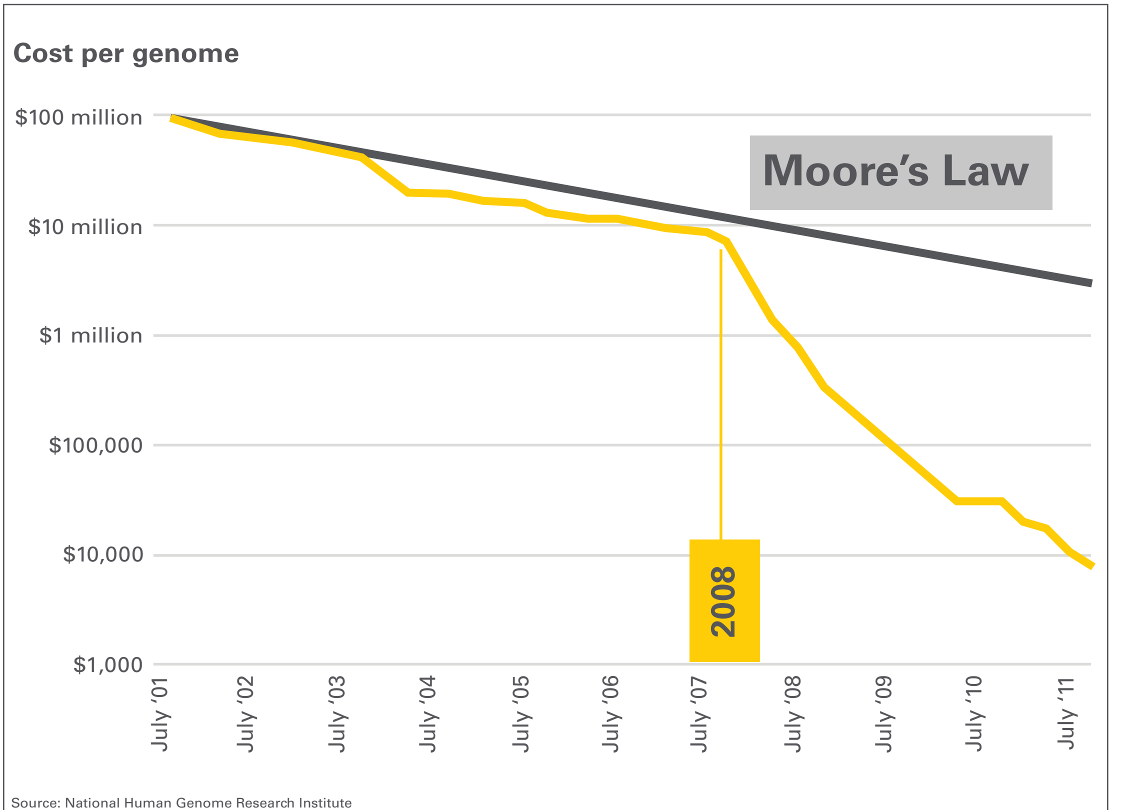
In the past, different parts of the world operated independently – Rome could fall without substantially affecting China. Now these pockets of isolation are largely gone, eliminated by growing webs of connection and interaction – business, finance and trade, travel, communication, science, government, political alliances, non-governmental organizations, and globe-spanning technical systems. Each part of the system has rich dynamics, and the parts link and interact with each other – the electrical grid with the Internet, the Internet with media and governance, governance with business, and so on. There are enormous benefits, but proliferating interconnections also create new failure modes – and failures can propagate quickly across the linkages.

2. Impacts of Technology

Advances in technology make it possible to create larger socio-technological systems with more scope for interactions, both in terms of scale and reach, and much faster speeds of interaction (nanoseconds instead of hours or days). Many of these advances can support improvements in our quality of life. On the other hand, technological systems are becoming so powerful that they are having increasingly disruptive impacts on society, the economy, and natural systems such as the climate system and biogeochemical cycles of nitrogen, phosphorus, and water. As a recent report pointed out, some of these technologies, such as synthetic biology, artificial intelligence, and nanotechnology, could actually have the potential for infinite impact and potentially constitute a threat to humanity.[11] Finally, we are experiencing the emergence of an "algorithmic world" where more control of complex technical systems is given over to machines. This has advantages but also poses dangers: Consider the "flash crash" of the stock market in 2010. One pernicious effect of this shift, as Nicholas Carr has recently pointed out, is that we move from being actors to observers and become isolated from the feedback that allows us to understand complex systems – we become mentally lazy.[12]

3. Rate of Change

Growing interconnection and accelerating technological change are increasing the overall rate of change. There used to be more time for discussion and reflection before action. Now, rapid change combined with 24-hour news cycles and social media create pressure to react quickly to problems. This makes it difficult to conduct the kind of systemic, interdisciplinary investigations needed to understand complex systems and develop fundamental solutions. Systems also change at different rates, which complicate strategy and policy for a wide range of actors, from companies to nation states to journalism organizations.[13] In some cases, the rate of technological change is becoming exponential. For instance, the rate of change in the biotechnology area now exceeds Moore's Law and has resulted in an exponential drop in the cost of reading genomic data in a little more than a decade (see chart below).[14]



Source: National Human Genome Research Institute

4. Population

More people create more potential interactions and increase pressure on resources and the environment, including more demands for food, housing, education, and services. Large-scale urbanization requires complex technical systems to support large numbers of people living in relatively small areas. As complex systems expert Eric Bonabeau has pointed out, "As population densities and the number of interactions among people increase, so does the probability of emergent phenomena."[15] For example, increasing population density vastly multiplies the damages inflicted by storms and hurricanes, with 2012's Hurricane Sandy as a premier example.

The Challenges

THE DANGER OF LINEAR THINKING IN COMPLEX TIMES

In simpler times, decision-makers could assume away complexity because the penalties were not always high. The difference today is that we are getting closer to operating boundaries of systems, closer to threshold effects and discontinuities, which means that complexity properties matter more. Two hundred years ago, the occurrence of large events in which small actions could ripple through a global system was unlikely. Today, suspicious activities at one airport can shut down flights between countries, infectious diseases can move thousands of miles in hours, and the bad behavior of traders at one bank can cause a recession – or worse – in the entire world economy.

We can no longer afford to ignore complexity. A nexus of interacting problems is looming that could threaten the viability of our civilization. It includes climate disruption, the end of cheap oil, a massive extinction of plant and animal species, the depletion of topsoil and fresh water in glaciers and aquifers, and other ecological impacts, but also includes worsening dysfunctions in our political and economic systems. Dealing with these interacting problems will require deep changes in the way we see problems and in our images of the preferred future.

The nexus of energy, water, and food – arguably the world's most critical resources – is a prime example of a complex systems challenge. Experts and decision-makers in each of these areas typically work in isolation from each other, and policy and funding decisions are made by separate agencies. Energy planners pay little attention to the water requirements of energy production; water planners assume they will have all the energy they need; and food planners, increasingly concerned about drought, call for pumping harder and drilling deeper for water. Few people are paying enough attention to the overall system and complex interactions between these resources.

As a result, new problems are emerging: Southern California Edison, which supplies electricity to Los Angeles, San Diego, and the surrounding region, has had to shut down two nuclear reactors for lack of cooling water; the water level in Lake Mead, outside Las Vegas, is at its lowest level in history and the falling water level could stop power production from the Hoover Dam in the next decade; and California's Central Valley is literally sinking as farmers draw down the aquifers that underlie it and support its crops. A more integrated approach to these three critical resources is urgently needed so our actions to deal with one issue do not worsen others.[16]

COMPLEXITY MEETS THE INSTITUTIONS WE RELY ON

Researchers looking at many different complex problems have come to similar conclusions that these problems cannot be adequately addressed by traditional linear approaches to policymaking that fail to consider the complexity of the system and interactions between causal factors.[17] Likewise, critical stories about complex topics may not be best expressed through traditional step-by-step storytelling. Complexity requires new narratives.

A handful of prime barriers to fostering complexity thinking and developing complexity-based strategies emerged from our interviews:

1. Outmoded organizational structures and capabilities
2. Decreasing diversity
3. Lack of a shared language to support dialogue or action

1. Outmoded Organizational Structures

One fundamental challenge that organizations face in dealing with complex issues is their departmental structure. Institutional silos can seldom achieve systemic solutions because they focus only on narrow parts of a system, not the whole and the related interactions. As one interviewee told us, "Silos think like silos and talk like silos. Even the smartest systems thinker cannot function well in siloed institutions." Complex problems are cross-disciplinary and our policymakers and journalists are in organizations that are not.[18] Few of our institutions that inform the public or make decisions for them (government bureaucracies, legislatures, think tanks, and journalism) are set up to approach issues in an interdisciplinary way.

Conventional organizational structures create other problems. As one interviewee explained, our political systems are "up against the world in terms of time and cannot do the more interdisciplinary, systemic investigations that are needed." Most policies are designed as responses to problems. But now we require real-time adjustment to emergent behavior. This need for persistent engagement often runs up against persistent policy inertia and our tendency to try to solve problems once and for all with legislation, which becomes locked in because policy gridlock prevents meaningful amendments that can respond to new technical, social, or economic realities.[19]

2. Decreasing Diversity

Diversity is the key to resilience in complex social-ecological systems. Loss of diversity leaves any complex system more vulnerable to threats. We are losing species (the extinction rate is approaching 1,000 times the historical background rate), languages (of the more than 6,700 languages spoken in the world, half are in danger of disappearing before the century ends), and crop varieties (spread of monocultures). As we destroy diversity, systems become more brittle, less resilient, and more prone to failure -- and this includes our problem-solving systems.

Scott Page, who directs the Center for the Study of Complex Systems at the University of Michigan, has made the point that diverse perspectives and heuristics are key to solving complex problems.[20] Different perspectives help overcome personal biases and "group think" and are increasingly recognized by effective leaders as a critical organizational trait.[21] The hectic hyper-speed pace of the news cycle has made it increasingly difficult for journalists to seek out the different viewpoints that make for the most useful journalism or even to distill the important stories from the lesser ones. In terms of problem solving, the endless revolving door in Washington, where the same people cycle between government and the government-focused private sector, also undercuts diversity.

3. Lack of Shared Language

We lack an appropriate vocabulary to discuss complexity. A recent book on complexity and foreign policy contained an entire lexicon that explained complexity concepts, such as emergence, path dependency, and non-linearity, in terms of their relevance to problem-solving strategies that one might find in the public sector. [22] Most people, however, cannot make heads or tails of this language. The complexity community has developed its own patois that limits concept transfer to existing and emerging problems areas. This places a high value on people and organizations that can move the concepts into practice in existing communities, from technology policy to transportation to national security.

Though few of the experts we interviewed thought that our policy system did a good job of addressing complexity, they felt strongly that the capacity could be improved, along with our ability to engage the wider public in complex issues that affect their lives. The issue becomes who should do this and how?

WHO CAN ADDRESS COMPLEXITY?

Translating the nuances and possible impacts of complex issues has often fallen on institutions such as think tanks. There are almost 7,000 think tanks globally, with approximately 30 percent of these in the United States, where the institutional genre was invented in the early 20th century.[23] These organizations turn out a constant stream of white papers, policy briefs, reports, and books, punctuated by workshops and conferences, all designed, in theory, to bridge the gap between knowledge and policy on a variety of complex issues ranging from climate change to cybersecurity. In 2012, the Wilson Center held a workshop titled "Beyond the PDF," to see whether a sample of Washington DC-based think tanks had managed, in an age of technological options, to move beyond the ubiquitous file format. The results were not encouraging. Though most think tanks have Facebook pages and Twitter accounts, social media is used largely to promote traditional products, not to fundamentally transform the approach to broad engagement around complex issues.

Quasi-governmental organizations tend to fare no better in their aspirations to move beyond the printed page. In 2014, the World Bank discovered that only a fraction of their massive intellectual output had been downloaded from their website or even referenced by other researchers (see box on next page).

Television, once described as a "vast wasteland," by former Federal Communication Commission Chairman Newton Minow, has occasionally risen above the banality of *Big Brother* and *The Bachelor* to tackle complexity in some innovative ways. One of the best examples is *Connections*, a ten-episode documentary television series produced by the BBC and written and hosted by science historian James Burke. It explored how various scientific discoveries, technical inventions, and historical world events were built from one another successively in an interconnected way to bring about particular aspects of modern technology. The series used everything from graphics to historical re-enactments to intricate working models to illustrate the complex connections of developments in different fields.[24]

In journalism, data-driven "interactives" in online stories try to present facts in more involving or personalized ways. For example, an online *USA Today* story about destructive natural gas accidents around the United States contained an interactive where readers could enter their zip code and see a map of accidents of different levels of seriousness nearest to them, accompanied by voice narration on the condition of the natural gas system in their state. Occasionally, these interactives begin to touch on complex interactions. Some online sports news stories contain "anatomy of a play" interactives, for instance, showing in detail how a particular offensive play causes defensive players to react.[25]

Journalism, however, is going through massive upheavals on every level and suffering declining trust on the part of citizens.[26] Besides broken business models, fractured audiences, and a media ecosystem that becomes more competitive (and complex) by the day, journalists have not necessarily found innovative and successful approaches to tell the complex systemic stories of our times. Whether it is climate change, global economics, poverty, the criminal justice system, or prescription drug abuse, journalists tend to produce stories that follow linear paths from fact to fact. Even the rise of interactives has not really taken on complexity. These systemic stories are not inherently boring, as some people claim, but rather journalists have not found a way to make them compelling.[27] This is in part because they themselves may not be good systems thinkers or, if they are, have been compelled to cover a narrow thematic silo or "beat." It may also happen because journalists have not found the right models for telling systemic stories of real complexity.

The Curse of the PDF

The World Bank occupies a number of glass-clad buildings covering two full city blocks in Washington DC. The bank employs thousands of bright, motivated people working on a host of complex issues, ranging from large infrastructure projects to economic development. In 2014, the bank undertook an analysis to see whether any of their reports ("knowledge products" in Bank-speak) were being downloaded. Of the 130,000 publically available World Bank documents, "About 13 percent of policy reports were downloaded at least 250 times while more than 31 percent of policy reports are never downloaded. Almost 87 percent of policy reports were never cited. . . . There are only 25 policy reports (2 percent of the dataset) that have more than 1,000 downloads during the period investigated (2008 to 2012)," the analysis found. Read more at: www.washingtonpost.com/blogs/wonkblog/wp/2014/05/08/the-solutions-to-all-our-problems-may-be-buried-in-pdfs-that-nobody-reads/

A Possible Solution

WHY PLAYABLE MODELS MAY PROVIDE AN ANSWER

The things we need to do to get better at dealing with complex system problems are not mysterious. For example, we need to:

Look at the relevant whole system – beyond narrow parts of an issue, single disciplines, and organizational silos;

Explore interactions between causal factors – how changing one part affects other parts and the whole;

Watch for emerging developments that require real-time adjustments;

View actions as experiments (because complex systems often have counterintuitive reactions to interventions) and be prepared to keep trying other actions to get the desired results.

One of the most effective ways to help people do this kind of thinking is to use playable models. *Budget Hero*, a online video game built by the Wilson Center and American Public Media and based on the Congressional Budget Office model of federal spending, is one example of this kind of approach.[28] Players are challenged to balance the budget by choosing from more than 70 policy options that involve cutting spending in different areas or raising various taxes. The model incorporates positive and negative arguments for each policy, drawn from scores of sources and vetted to ensure the game is nonpartisan.

One *Budget Hero* player wrote, "The complexity of the issues was much more apparent. I realized that the decision-making process is a lot more extensive than plain black-and-white values." Another player observed, "I didn't really understand how complex the budget issues are. This is going to be difficult for either party to resolve. How did we get in such a mess? Tough choices are going to have to be made." *Budget Hero* players who were surveyed, both conservatives and liberals, came away with a more sophisticated appreciation of the budget challenge and an ability to see through the simplistic, inaccurate statements politicians often make about the budget. After playing the game, many were critical of what they saw as superficial coverage of the budget in the media.

Budget Hero is effective because it meets the kind of criteria mentioned above. It looks at the whole budget, not just a part. It shows people who use it how choices in one area have consequences in other areas. It highlights how any emerging development – an economic downturn, a new policy goal requiring funding – requires immediate adjustments. Most importantly, it allows people to experiment and see the consequences of different choices. It engages people and deepens their understanding through active involvement.

The power of models and simulations built as games to help people understand complex systems has only begun to be taken advantage of. Ideas about games and play being trivial and juvenile tend to drive "serious" organizations – like newsrooms or think tanks – away from using these tools. We use the term **playable model** to move away from these prejudices and to strip the concept down to its roots and away from distractions having to do with "gamification."

Game designers, media theorists, and literacy scholars such as Eric Zimmerman, Katie Salen, Henry Jenkins, and Jim Gee have argued persuasively that video games, a form of playable model, are unlike other forms of media and uniquely suited to foster systems-thinking. "Games, are in fact, essentially systemic," writes Zimmerman.[29] "Model-based reasoning – interacting with a model – whether it's as simple as a fish tank or very complex, that's the core of modern thinking," said James Paul Gee, a literacy scholar at the University of Arizona and author of *What Videogames Have to Teach Us About Learning and Literacy.* "If you want people to learn you cannot just give them words, you have to give them experiences. Experiences are what give the words meaning. That's why you use interaction."

Video games are different from other forms of media because they allow players to engage directly with the processes of a system. Ian Bogost said that, although games "service representational goals akin to literature, art, and film," they "require user action to complete [that] representation."[30] Designers construct a video game as a set of dynamic interrelated parts – and gamers come to understand intuitively that touching any one part of the system affects the whole thing.[31]

"Games are a beautiful tool in which systems can be made really apparent, as well as ideas of complexity, ideas of emergence, and turning notions of linear causality on their head," said Katie Salen, game designer and co-founder of the Institute of Play. And video games, unlike just any kind of simulation, are dynamic models that one *plays* with.[32]

Understanding the psychology of play is crucial to understanding the potential in playable models. Some hold that games work well as teaching and leisure tools because of their tendency to produce Mihaly Csikszentmihalyi's "flow state," a balance between mounting skill and challenge that provides focus, control, and intrinsic pleasure.[33] Others laud games for providing player-learners with a kind of "psychosocial moratorium," a safe space for experimenting "where real-world consequences are lowered."[34] There is enormous value in creating safe spaces for policy-relevant experimentation in a world where decision-makers have few opportunities to play with a system.

"Play provides the space for asking 'what if…' questions," Salen said. "It creates a kind of openness to seeing, observing, and experiencing. Often when people are in a state of play they try things that they would never try before in the real world. There's a kind of freedom to that. It opens up the space of possibility in one's mind. That's where you get breakthroughs, like, 'Oh, I never thought that I could think about it that way.'"

The free-form environment in games allows for experimentation. "The act of play is not so different than the scientific process," said John Sharp, professor of game design and learning at Parsons The New School for Design and a Knight grant recipient for his work on Data Toys, an attempt to model complex systems in the news. "You're coming up with a theory, testing out that theory, and evaluating the results of what happened."

Gee calls this the "probe, hypothesize, reprobe, rethink cycle." In other words, great video games require their players to constantly reassess the meaning and efficacy of their actions within a virtual world.[35]

In the mid-2000s, excitement over what became known as "serious games" was high. But in the excitement over video games as a learning tool, our interviewees said, the essence of what a video game *is* got lost. Nonprofits and educators rushed in to take advantage of this new medium because they wanted to make learning "fun" for kids. But often this led to shoehorning content – math, history, economics – into a video game format rather than taking advantage of video games as a native way to foster deep understanding of complex topics or complexity itself.[36] "In other words, 'serious games' became 'here's the message; let me interject it,'" Zimmerman said – a misunderstanding of the form, which led to the development of mediocre games. And if a game is mediocre, people are not going to play it.[37]

The potential for playable models that can support systems learning and scale to millions of people remains untapped. While acknowledging the limited development of high quality games in this area so far, people we interviewed remained upbeat about playable models themselves as an important learning tool for a number of reasons.

1. The Power of Experiential Learning

Experiential learning is learning through experience or, more specifically, learning through reflection on experience. Gee and Salen spoke about the experiential nature of learning that happens in a game. This begins at an early age. When playing "pretend," a child "achieves a functional definition of concepts or objects" by learning to act independently of perception (substituting a play-object for a "real" one).[38] Raph Koster argues that because "they are about teaching underlying patterns," – we must actively deconstruct a kind of living, breathing word problem to see the abstract simulation driving it.[39] Salen also said that the ability to "change variables in a game" is part of what allows people "to develop theories" when playing, which is crucial to the learning process.

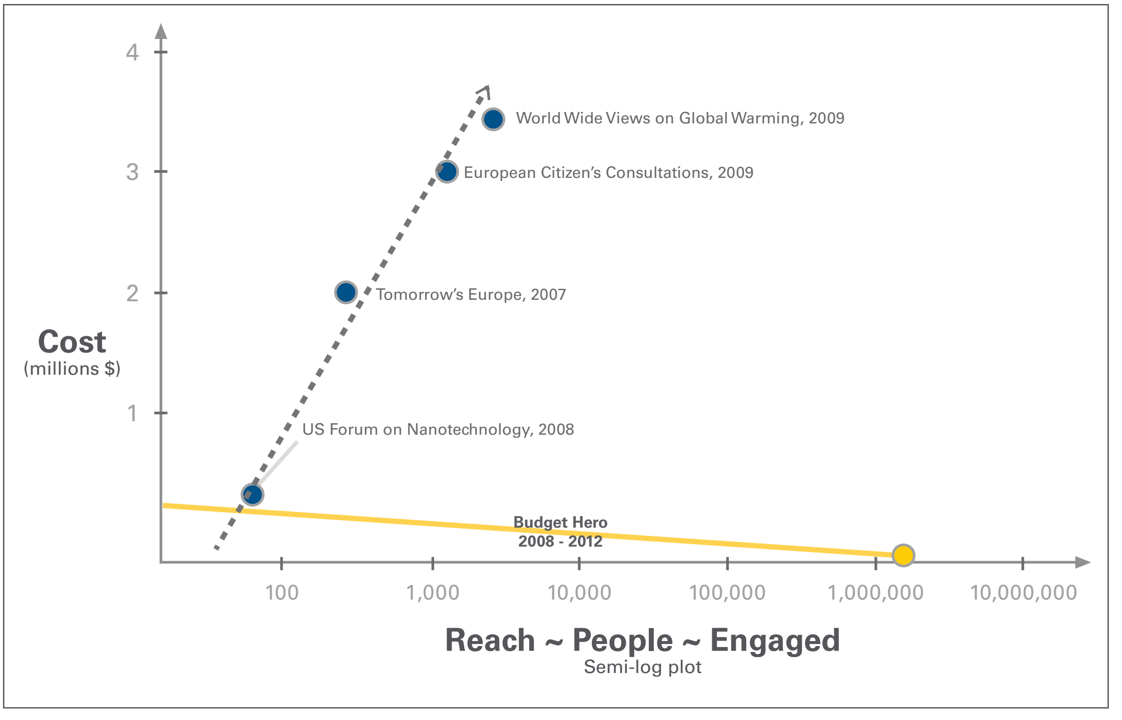
2. The Untapped Treasure Chest of Models

Much has been written about federal data collection and the coming age of Big Data. The total federal spending on big data resources is expected to grow to $7.2 billion by 2017 with a compound annual growth rate of 8.2 percent according to estimates by Deltek, an IT consultancy.[40] Recent efforts at federal, state, and local levels around "open data" have started to make data sets available to wider audiences and citizens have been encouraged through hackathons and data jams to develop ways to better aggregate, visualize, and share data.[41]

As valuable as the data is, it is the models that allow for the explorations and projections that drive policy. Most governments make significant investments to develop and update models used in areas such as natural resource management, budget planning, and health care. Not all of these are complex systems models, but many do allow users to explore the interactions of multiple variables over time and space. However, these models are buried deep inside government agencies or controlled by government contractors. What is needed are not just efforts focused on open data (data.gov), but initiatives that provide more open access to models and make these playable with good data visualization and interactive interfaces accessible on multiple platforms, from desktops to tablets and smart phones.

3. The Ability to Improve Public Engagement around Public Issues

One of the advantages that playable models offer to think tanks, quasi-governmental entities, government institutions, and news organizations is the ability to fundamentally change the economics of public engagement, creating a platform that can scale to potentially millions of people. A 2010 analysis of various public engagement initiatives found that it cost an average of just under $1,000 per person engaged (compared to under $.25 per person with *Budget Hero* after four years, see chart on next page).[42] Obviously, playable models are not a substitute for face-to-face meetings or scholarly reports, but the learning can still be very rich. In addition, face-to-face meetings are often one-offs and suffer from small numbers that make statistical inferences problematic. This graph shows the difference in the economics of engagement if one moves from a fixed-cost to a software model that underpins most online games.



We desperately need new approaches to public engagement that go beyond meetings and can reach a "public" that has become ever more complex.

As complexity has been increasing, policymakers have become more isolated from those they govern. As Don Kettl, the former Dean of the University of Maryland School of Public Policy, told us, "The more indirect, complex and leveraged government becomes, the harder it is to understand."[43] Recent research by Jennifer Bachner and Benjamin Ginsberg at Johns Hopkins University found "a substantial cognitive and perceptual gulf between official and quasi-official Washington on one hand and the American public on the other."[44]

4. The Crisis (or Opportunity) in Journalism

That contemporary journalism is in crisis is not news.[45] The rise of the internet has decimated the traditional news business model, while audiences have fractured and competition has increased. Despite increased (and sometimes very effective) use of interactive features, many journalists continue to shy away from grappling with complexity.. [46]

There is tension between the reactive nature of traditional journalism — covering recent events — and going deep to reveal the roots of a problem or explain how the problem spaces operate. "By its nature news is kind of ephemeral," said Aulistair Dant, interactive designer at *The New York Times*. "Even when *The Times* or somewhere that has a big budget can allow a reporter to really dig into something for a long time, it still seems to be understood that whatever it is that they've written is going to be tomorrow's chip paper."

Ultimately, there may be a cultural divide between the making of traditional news products – an article in a newspaper or a blog post – and the making of something more long lasting like a playable model. Also, the confusion reigning in contemporary newsrooms about everything from financial sustainability to reaching audiences in the hyper-competitive media ecosystem cannot be underestimated.[47] Scott Klein, assistant managing editor at ProPublica, also expressed concern that that using playable models in journalism would have too much "conjecture" in it. "Journalists wouldn't feel comfortable doing it," he said. "Journalism is not about conjecture. Instead, journalists ask themselves, 'What is the phenomenon that is occurring that we should be covering?'"

However, some people were more optimistic. Sisi Wei, news applications developer at ProPublica and one of the industry's leading advocates of news games, did not think the technological barriers were an actual problem. Rather, she pointed to the fact that few reporters are trained to report stories that would lead to playable models. She said when a journalist reports on a story that is going to turn into an interactive game, for example, he or she needs to ask different types of questions and bring back different types of data. Wei also said that anyone who is currently making interactives was "capable" of making a game. "They just haven't thought about it that way before . . . Games are a goldmine that people haven't figured out how to use well," she said.

Michael Skoler, former head of digital for Public Radio International and one of the co-creators of *Budget Hero*, felt strongly that the ability to create a model for people to play with and then let them explore it in an open-ended way, drawing their own conclusions, was "overwhelmingly positive." He even said players should be able to add to journalistic games the way they do in commercial games, though he conceded, "This will be a tough concept for journalists."

At the heart of the matter about playable models is one of the great struggles currently taking place in contemporary journalism: Who is in control?[48] In a game like *Budget Hero*, there is no prescribed outcome other than balancing the budget to win. Likewise, the Knight Foundation-funded Data Toys project chose to create open-ended experiences for players. Both of these projects were about showing cause and effect. As Salen pointed out, games are inherently unpredictable. "When we talk about emergence in games, it has to do with the fact that when there is play involved, things come up that no designer could have predicted," she said. And, according Skoler, games are best when they are "exploratory."[49]

In other words, playable models are not about dictating answers but rather showing the inter-connectivity between a set of dynamic parts and letting players develop a deeper understanding of a given problem space by engaging with those interconnections.

In our minds, this maps nicely over the journalistic value of striving for objectivity and letting readers draw their own conclusions based on the facts. But the truth is, as journalists and news organizations struggle to adapt to a new media environment wherein they are no longer the sole authoritative voice, this may be a tricky issue. Journalists and news organizations are no longer the "gatekeepers" of vital information.[50] We would argue this is the perfect time for introducing something like playable models – an acknowledgement of this shifting power dynamic.

Moving Forward

“Having the money to do the work is certainly required, but it’s not a sufficient solution. It’s necessary but insufficient. What you really need is this community that doesn’t exist yet.”

Ian Bogost

In writing this paper, we were struck by the imbalance between problems and solutions. People were quite articulate about the challenges, but few could offer solutions. Some were realistic about how long it could take for systems thinking to effectively penetrate our problem-solving strategies – decades, not years – and were afraid that the planet cannot wait that long.

People who had invested significant time and effort in pushing games as a means to better understand complex systems felt that so far the games have failed to reach their promise in terms of engaging people around serious issues.

One idea noted repeatedly was the lack of any organized group dedicated to taking on complexity as an issue, either from the public policy side or from the media community. This means going beyond groups that focus on complexity as a research issue – like the Santa Fe Institute – to people, organizations, and funders that focus on improving our ability to engage people outside research settings in complexity and doing this in a way that can scale.

The problems with not having a community are multifold. First, work done in this area is almost always on what Ian Bogost, author of *Newsgames*, called “borrowed time.” Second, no one we interviewed is sure where this work should be housed or who would fund it. Questions remain even at the level of who should be on a team that makes playable models and how these people would interface with more traditional, legacy organizations in government, academia, or journalism. Many interviewees spoke of the importance of bringing in people from multiple disciplines, but few knew how to sustain such interactions beyond one-off workshops or conferences.

The primary challenge at this point may be organizational. How can we build a community of practice that includes people who understand the nature of complexity, those who must address its challenges, and those who may have solutions to communicating and engaging the wider public?

INTERVIEWS

Over a six-month period, the authors conducted in-depth interviews with the following people:

Don Kettl, former Dean, School of Public Policy, University of Maryland, https://www.publicpolicy.umd.edu/faculty/donald-kettl

Ed Tenner, Visiting Scholar, Princeton University, http://www.edwardtenner.com

Linda Booth Sweeney, Systems Educator, http://www.lindaboothsweeney.net

Mitch Waldrop, Editor, *Nature Magazine*, Author, *Complexity: The Emerging Science at the Edge of Chaos,* http://communications.yale.edu/poynter/2011/03/28/mitch-waldrop

Roland Kupers, Visiting Fellow, Oxford University, Consultant on complexity and resilience, http://www.rolandkupers.com

Clem Bezold, Founder and Chairman of the Board, Institute of Alternative Futures, http://www.altfutures.org/clement-bezold-phd

Willis Goldbeck, Program Coordinator, Foresight Education, U.S. Department of State, Office of Overseas Schools, http://www.fcaq.k12.ec/gin/kn_speakers/wgoldbeck.html

William Starbuck, Lundquist College of Business, University of Oregon, http://pages.stern.nyu.edu/~wstarbuc/

Brad Allenby, Lincoln Professor of Engineering and Ethics, Professor of Law, Arizona State University, https://webapp4.asu.edu/directory/person/744560

Frank Pietrucha, Author, *Supercommunicator: Explaining the Complicated So Anybody Can Understand*, http://www.supercommunicator.com

Edward Finn, Director, Center for Science and the Imagination, Arizona State University, http://csi.asu.edu/people/ed-finn/

Dennis Meadows, Emeritus Professor of Systems Management, University of New Hampshire, http://en.wikipedia.org/wiki/Dennis_Meadows

Ira Flatow, Host, Science Friday, http://www.sciencefriday.com/about/about-ira-flatow.html

Duane Elgin, Author, *The Living Universe: Where Are We? Who Are We? Where Are We Going?* (2009); *Promise Ahead: A Vision of Hope and Action for Humanity's Future* (2000), *Voluntary Simplicity: Toward a Way of Life that is Outwardly Simple, Inwardly Rich* (2010, 1993 and 1981), http://duaneelgin.com

David Colander, Christian A. Johnson Distinguished Professor of Economics at Middlebury College, Co-author of *Complexity and the Art of Public Policy*, http://www.middlebury.edu/academics/econ/facultyofficehours/node/51761

Gene Bellinger, Systems Thinker, Author, *Beyond Connecting the Dots* (with Scott Fortmann-Roe), http://www.linkedin.com/in/systemswiki

Scott Page, Director, Center for the Study of Complex Systems, University of Michigan, http://vserver1.cscs.lsa.umich.edu/~spage/

Alastair Dant, Interactive Developer, *The New York Times*, http://www.recursiveflow.com/

Anjalli Mullany, Senior Editor, *Fast Company*, http://www.fastcompany.com/user/anjali-mullany

Scott Klein, Assistant Managing Editor, ProPublica, http://www.propublica.org/site/author/scott_klein

Sisi Wei, News Application Developer, ProPublica, http://www.propublica.org/site/author/sisi_wei

Joaquin Alvarado, Vice President, Strategy, Center for Investigative Reporting, http://cironline.org/person/joaquin-alvarado

Michael Skoler, General Manager, Public Radio International, http://www.pri.org/people/michael-skoler

Paul Steiger, Founder and Executive Chairman, ProPublica, http://www.propublica.org/site/author/paul_steiger

Katie Salen, Game Designer, Founder, Quest to Learn Schools, Co-Author, *The Rules of Play*, Co-founder, Institute of Play, http://www.cdm.depaul.edu/people/pages/facultyinfo.aspx?fid=1037

Eric Zimmerman, Game Designer, Professor, Games Center, New York University, Co-author, *Rules of Play,* http://gamecenter.nyu.edu/tag/eric-zimmerman/

Ian Bogost, Game Designer, Author, *Newsgames*, Professor, Georgia Tech, http://www.iac.gatech.edu/faculty-and-staff/faculty/bio/bogost

John Sharp, Game Designer, Professor, Parsons School of Design, http://www.newschool.edu/parsons/faculty_program.aspx?id=91269

Jim Gee, Literacy Scholar, Author, *What Videogames Have to Teach Us about Learning and Literacy*, https://webapp4.asu.edu/directory/person/1054842

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48 *Ibid*.

The mission of the Science and Technology Innovation Program (STIP) is to explore the scientific and technological frontier, stimulating discovery and bringing new tools to bear on public policy challenges that emerge as science advances. We work across a range of issues from strategic planning to risk management, technology assessment to regulatory reinvention, both domestically and internationally.

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